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South Biscayne Bay Water Quality: A Twelve Year Record for Biscayne National Park

United States Department of the Interior

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Southeast Region

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SOUTH BISCAYNE BAY WATER QUALITY: A TWELVE YEAR RECORD FOR BISCAYNE NATIONAL PARK

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TABLE OF CONTENTS

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ABSTRACT

An observational study was performed on a set of water quality data obtained in time and space over the Biscayne Bay, Florida. In all, 131 sampling episodes were carried out over a period of about 12 years.

Data summaries of 11 variables were calculated for all of the sampling stations and the categories of sampled depths. Based on a multivariate analysis of the variances it was concluded that there is no significant variation in the sampled variables with depth. On the average, ammonium, turbidity, and dissolved oxygen were the most variable; pH and the nitrate ion were the next most variable while salinity and the conductivity were the least variable.

Heuristic approaches that rely on standard hypothesis testing were applied to investigate the significance of a 1979 change in water quality sampling techniques. The correlation matrix of the Before-change and that of the After-change data were used in this regard in addition to the comparison of the corresponding basic statistics. The change was not significant at the 5% level.

Cluster analysis of the samples collected from 1979 to 1984 showed that there were basically two clusters of stations: those at the mouth of the canals and nearshore and those that were offshore. Further analysis of the offshore stations provided a basis for deleting some of those stations without losing valuable information on the microecosystem around the deleted station.

The records of the Moody and Mowry canal discharges into the Bay were combined with the sampled bay water quality data in order to investigate the impacts of such discharges. Thresholds were assumed for the discharge and water quality variables. Because of the arbitrary choice of the thresholds, only relative inferences were made concerning the distribution of ion concentration along the axis of canal discharges.

The Kendall rank correlation method was used to investigate possible trend in the data sets and to determine an optimal sampling frequency. Independence between successive observations was assumed to be established if the calculated rank score exceedance probability was greater than 0.05. Based on this criterion, the monthly observations were found to be independent. The calculated exceedance probability did not change significantly with increasing sampling frequency. Thus, the analyses did not indicate any trend or seasonality. This, however, may be because measurements were made just once, and in a few cases only several times in any one month.

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

The assistance of Mr. Richard Curry, Park Oceanographer and Ms. Jennifer Bjork, Bio-Technician in collating the date used in this study is appreciated . Special thanks is accorded to Dr. Steven Coffer-Shabica, Research Coordinator for his many helpful suggestions and untiring support of this research project.

1.0 INTRODUCTION

The purpose of sampling hydrologic variables, both in space and time, is to reduce uncertainty and hence provide reliable data for decision making in water and other natural resources management. It is obvious, however, that large scale hydrologic systems, as in the National Parks, are very heterogeneous. It will be prohibitively expensive to sample them in detail. Thus, a trade-off arises between the cost of data acquisition and the predictive accuracy that is consistent with mandated Park Service activites.

In designed data collection networks, this trade-off is assumed to have taken place. In situations, such as in this study, where one is obliged to use existing data without the benefit of design, certain inherent problems exist. In either situation, the objective is to supply information which is directly useful in understanding the recycling of water and nutrients in natural ecosystems and in studying the impact, on habitats, of man's action on such natural environments.

The objectives are to :

1) calculate and present data summaries of each sampled variable by station and region of the Biscayne Bay;
2) investigate the variation of the sample statistics with depth of measurement for representative stations of the Biscayne Bay;
3) compare the time and space characteristics of the water quality variables sampled in 1972-1978 and in 1979-1983 at the same stations;
4) divide the Biscayne Bay into homogeneous water quality regions and investigate the possibility of reducing the number of sampling stations;
5) study the quality impact of canal discharge into the bay;
6) combine the sampled variables into subgroups (factors) which convey the essential information contained in the membership of the subgroup;
7) identify the variables with large variances and recommend sampling intervals for these variables; and,
8) investigate possible trends in the data sets and determine the optimal sampling interval.

2.0 DESCRIPTION OF AVAILABLE DATA

The National Park Service has collected 12 years of monthly water quality data. The network started with 60 stations at each of which were sampled five variables. Over time, the number of stations has changed and is now about 31. The number of parameters in contrast has increased by about three fold. The sampling was not continuous and the period of sampling varied from 3 to 8 months in any given year. Several samples, typically one, were collected within a sampled month.

About 25 years of rainfall data are also available. These data were recorded at four rain-gage stations. Canal discharge data were also available although the sampling strategy changed in 1979. These discharges, were, for the most part, controlled.

Thus, in addition to data collection design problems, the data sets described above had characteristics that required the application of relatively sophisticated statistical techniques in order for the analyst to supply useful information for reliable inferences about the hydrologic processes and/or for decision making. Among these chracteristics were inherent randomness, uncertainty and nonstationarity in rainfall, discharge, and water quality indicators. Further, the data may be inconsistent by virtue of the change in the manner of data collection in 1979. A meaningful representative value of rainfall for the area was difficult to obtain because of the highly localized nature of rainfall events.

Water quality data were received in two forms, a bound computer printout and two floppy 5 1/4-inch diskettes. Because of persistent difficulty in abstracting the data from the diskettes they were typed onto disk storage from the printout. The variables and parameters abstracted from the printout, for each sampling date, include: record number, station number, sampling time, salinity, conductivity, water temperature, turbidity, pH, dissolved oxygen, ammonium, nitrite, nitrate, phosphate, and air temperature. After debugging for typographical and other errors the data set was saved in two files:

QUALI.DAT (Records 0001-2500) QUAL2.DAT (Records 2501-5166).

In the above files, missing data are represented by 9.99, 99.99, or 999.99 depending on the number of columns used to record the variables. The files were combined in the hard disk and named QUAL.DAT.

Figure 1 is the a map of the project area and includes canal and bay water-quality sampling stations. Canal discharge data were received in the form of hard copy. The discharge records include:

for Black Creek	-	1972 to 1982
for Moody Canal	-	1972 to 1982
for Mowry Canal	-	1972 to 1982
for Florida City Canal	-	1972 to 1974
for Card Sound	-	1972 to 1974.

The Black Creek and Card Sound data were not used in the analyses because the creeks were outside of the zone of Bay water-quality sampling. Florida City Canal data have missing data within the only two years of data available. It, was therefore, also not used. Only the Moody Canal and Mowry Canal data were therefore used in the analyses. Missing data were represented by 9999. Flow data were stored in file the FLOW'.DAT. Entries included the Julian date; Moody and Mowry flow data for this date and for four days prior. A second file, DATE.DAT, contained entries for Bay water-quality sampling date and record number.

2.1 Randomness of the Sampling Frequency

Since data were not collected at constant time intervals, the standard methods of time series analysis cannot be applied. Monparametric methods, such as, rank correlation may be used, however, to determine the appropriate sampling frequency for the water quality indicies. Table 1 lists the sampling dates and the number of intervals between episodes for the 1979 through 1984 data. The statistics are:

		Number of cases	54
Minimum	1 day	Standard Deviation	30 days
Maximum	223 days	Standard Error	4 days
Mean	36 days	Skewness	5.

Figure 1. Location Map of Sampling Stations

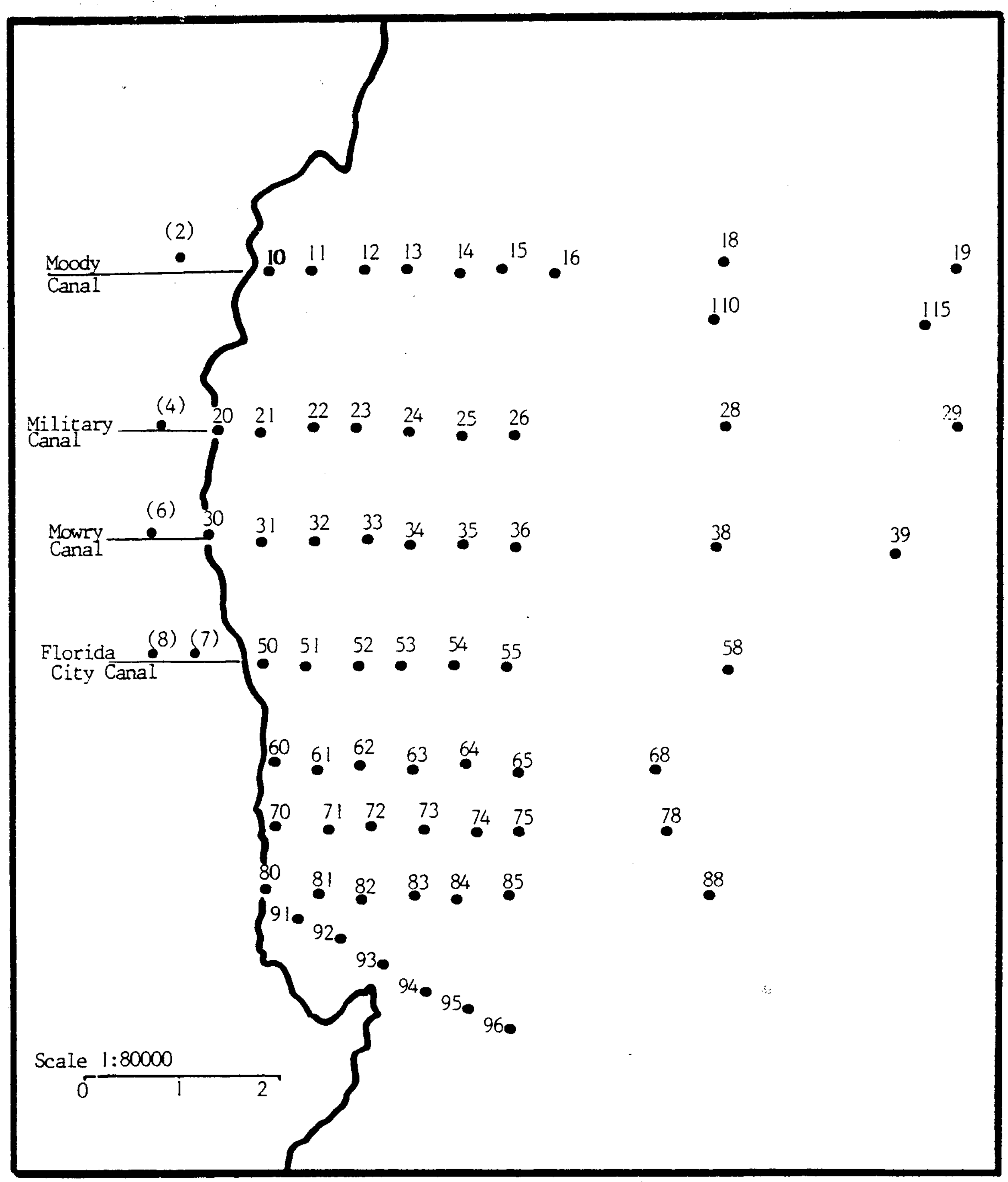


TABLE 1. Sampling Dates

Current Date	Next Date	Interval (days)
79026	79043	17
79043	79071	28
79071	79108	37
79108	79140	32
79140	79163	23
79163	79199	36
79199	79226	27
80021	80044	23
80044	80072	28
80072	80073	1
80073	80105	32
80105	80135	30
80135	80170	35
80170	80198	28
80198	80224	26
80224	80261	37
80261	80289	28
80289	80318	29
80318	80351	33
80351	81019	33
81019	81049	30
81049	81105	56
81105	81133	28
81133	81169	36
81169	81198	29
81198	81226	28
81226	81261	35
81261	81289	28
81289	81323	34
81323	82019	61
82019	82041	22
82041	82083	42
82083	82119	36
82119	82134	15
82134	82168	34
82168	83025	223
83025	83026	1
83026	83049	23
83049	83145	96
83145	83165	20
83165	83200	35
83200	83230	30
83230	83266	36
83266	83286	20
83286	83322	36
83322	83349	27
83349	84046	62
84046	84076	30
84076	84137	61

Since the sample mean and standard deviation are significantly different, the sampling intervals are not random so that stochastic methods are also not applicable.

Both the Bay quality and the Canal quality and quantity data required extensive preprocessing before any methods of analysis could be implemented. After the general processing which are described below, segments of the overall data which met conditions for applications of each technique were abstracted and further processed before use.

The FORTRAN program FLOW.FOR combines the contents of DATE.DAT and FlOW'.DAT. The resulting data file (FLOW.DAT) contains the record number, station number, the date, the Moody flow data, and the Mowry flow data for the corresponding date.

The FORTRAN program FLOWQUAL.FOR incorporates the flow data in file FLOW.DAT into the Bay quality data in file QUAL.DAT for measurements between 1972 and 1982. The Canal data were not available beyond the middle of 1982. There is a possible limitation in the interpretation of analyses using these data. Consider the sampled stations for the Mowry Canal as shown in Figure 1. The flow was measured at or near station 6. The entry in the output file, FLOWQUAL.DAT assigns this same flow to stations 31, 32, 33, 34, 35, 36, 38, and 39. Hence, the tendency will be to overestimate the measured quality parameters at these stations when canal quality is worse than the Bay quality and vice versa.

Only the following six of twelve possible water quality variables were retained in FLOWQUAL.DAT: salinity, conductivity, temperature, turbidity, pH and dissolved oxygen in addition to the depth measurements. The entries in FLOWQUAL.DAT will be used in section 6.0 to investigate the order of interaction between discharge and the sampled variables.

In the following sections the objectives identified in Section 1 are addressed in detail. For each objective, the preprocessing of the original data is described. Then the methods applied are described followed by a discussion of the results of the analyses. In meeting these objectives we were guided by the need to apply techniques and procedures that were commensurate with the quality of the available data.

3.0 DATA SUMMARIES AND VARIATION OF BAY WATER QUALITY WITH DEPTH

The objectives were to calculate and present data summaries of the sampled variables by station and region of Biscayne Bay and to investigate the variation of the sample statistics with depth of measurement for representative stations of the Bay.

Description of Data

The original data set, contained in QUAL.DAT, was sorted by station and by depth category (in meters). The sampling depths were categorized as follows in order to facilitate interpretation of the sample statistics to be computed:

Depth $\leq$ 0.2m	Category 1
0.2 $\leq$ Depth $\leq$ 0.5m	Category 2
0.5 $\leq$ Depth $\leq$ 1.0m	Category 3
1.0 $\leq$ Depth $\leq$ 2.0m	Category 4
Depth > 2.0m	Category 5.

A preliminary analysis showed that many of the over 67 stations were sampled few times at various depths and that some of the variables were not sampled at all on some of the sampling days. A combination of these two sources of missing data reduced the number of stations that could be used to test the variability of the water quality variables by depth and by region of the Bay. The following 11 bemchmark stations were selected as representative of the several zones of the Bay : 04, 11, 15, 18, 19, 29, 35, 29, 78, 92, 96.

Methods

The approach was to determine if the difference in sample means computed for the different depths was attributable to just random variations alone or to both random and systematic variations. The Analysis of Variance method was used for this purpose. This procedure assumed that the variance for the various sampling depth categories was constant. The observations were assumed to be independent and normally distributed. The null hypothesis was that the means for the depth categories were equal against the alternative hypothesis that at least two of the means were not equal at a chosen significance level. When this hypothesis is true, the variance

$$f=var1/var2 \qquad (3.1)$$

ratio is a value of the random variable F having the F-distribution with $n_1=k-1$ and $n_2=k(n-1)$ degrees of freedom for var1 and var2, respectively. The variable, var1, is the cummulative variance due to both systematic and random variation while var2 is the cummulative variance due to random variation only. The variable k is the number of depth categories and n is the sum of the number of observations in each depth category. The decision criterion was not to reject the hypothesis and conclude that measurements for the various depth categories had the same mean if the theoretical f-value was greater than the computed f-value.

Discussion

The STATISTICS module of the SYSTAT statistical package was used to compute the sample statistics which included the minimum, maximum, mean, and the standard deviation of the water quality variables based on the station and the depth category. Appendix 1. contains the statistics for the 11 benchmark stations. The same information for all 67 stations and 12 variables in the initial data set were saved in file STATS.DAT contained in the solution diskette submitted with this report.

A computer program was written to compute the f-value for each variable-station combination. Table 2 is a tabulation of these values and also of the corresponding degrees of freedom, n_1 and n_2. The blank spaces in the table correspond to situations when samples were taken at only one depth (f_1 = 0) or when the total sample size for all depths was less than 2.

The results show that 96 of the 99 variable-station combinations support the conclusion that measurements at the different depths have the same mean at the 5% level of significance. Thus, the analyst may use data measured at any one of the five depth categories or pool the data for all the depth categories. It was noted that, at this level of significance, the hypothesis that the variances were the same was not supported for over 50% of the variable-station combinations.

Table 2. Calculated F-Statistic by Station and Variable

		STATION										
VARIABLE		04	11	15	18	19	29	35	39	78	92	96
SALT	f	2.95	0.33	0.22	0.34	0.11	0.13	0.22	0.80	0.51	0.87	0.35
	n_1	2	3	4	4	4	2	3	4	3	3	4
	n_2	100	146	143	114	90	24	105	97	112	122	130
COND	f	4.23	0.29	0.08	0.42	0.34	0.12	0.50	0.79	0.55	0.95	0.15
	n_1	2	3	4	4	4	2	3	4	3	3	4
	n_2	109	149	149	125	100	24	114	103	119	124	134
TURB	f	5.33	1.69	3.13	0.96	0.68	0.54	2.19	0.83	4.10	10.8	1.89
	n_1	2	3	4	4	4	2	3	4	3	3	4
	n_2	68	115	112	83	59	11	77	66	82	97	100
PH	f	9.05	63.4	2.69	0.65	1.68	3.61	1.33	0.89	0.93	1.05	1.14
	n_1	2	3	4	4	4	2	3	4	3	3	4
	n_2	100	103	102	107	90	23	104	93	102	92	103
DO	f	0.94	4.92	0.82	0.75	1.75	0.07	0.74	1.69	1.04	2.30	0.71
	n_1	2	3	4	4	4	2	3	4	3	3	4
	n_2	107	89	95	99	99	24	97	93	92	81	93
AMO	f	0.14	0.44	0.22	1.15	0.21		0.39	1.69	0.04	0.27	0.69
	n_1	2	3	4	4	4		3	4	3	3	4
	n_2	48	41	40	41	40		40	41	38	35	40
NITRI	f	0.84	0.10	0.94	1.69	1.43		0.76	1.04	0.03	0.91	0.11
	n_1	2	3	4	4	4		3	4	3	3	4
	n_2	50	42	40	42	40		41	42	39	36	40
NITRA	f	1.72	0.14	1.01	0.36	0.15		0.66	0.16	0.61	0.39	0.13
	n_1	2	3	4	4	4		3	4	3	3	4
	n_2	49	41	40	42	40		41	40	40	36	40
PHOS	f	1.79	0.61	0.97	1.56	0.35	3680	0.44	0.33	0.64	0.14	1.08
	n_1	2	3	4	4	4	2	3	4	3	3	4
	n_2	38	35	33	35	34	1	34	35	33	29	34

Legend:

SALT = Salinity
COND = Conductivity
TURB = Turbidity
PH = pH
DO = Dissolved Oxygen
AMO = Ammonium Ion
NITRI= Nitrite Ion
NITRA= Nitrate Ion
PHOS = Phosphate Ion

The variability in the water quality variables was measured by the coefficient of variation defined as the ratio of the sample standard deviation to the sample mean. Table 3 shows these values for most of the variables sampled at the benchmark stations. The blank spaces represent cases when the sample size for each of the depth categories, at a station was less than four. The choice of four samples was arbitrary. The last column in this table is the mean coefficient of variation for the variable. This column shows that, on the average, the most variable water quality parameters were ammonium, turbidity, and dissolved oxygen. The least variable parameters were water salinity and conductivity.

4.0 BEFORE (1972-178) AND AFTER (1979-1983) STUDY OF CHANGE IN MEASURING TECHNIQUES

The goal was to compare the time and space characteristics of the water quality variables sampled in 1972-1978 and in 1979-1983 at the same stations. Specifically, the object was to assess the effect of the change in the measuring techniques for water quality variables.

Description of Data

The starting point was the data set of file QUAL.DAT. To maximize the available data for the analysis of this section only water quality variables that were measured, for the most part, in both the Before and After periods were used. These included salinity (SALT), conductivity (COND), temperature (TEMP), turbidity (TURB), and the sampling depth (DEPTH). Records with one or more missing values were not included.

Methods

As observed earlier, sampling episodes were nonregular. They were not completely random because of scheduling of the sampling days. In the former case, time series methods that identify break points in the series cannot be applied. In the latter case stochastic analysis may not be justifiable.

Table 3. Coefficients of Variation by Station and Variable

	STATION										
	04	11	15	18	19	29	35	39	78	92	96	AVG
SALT	.61	.26	.11	.06	.06	.04	.13	.07	.08	.15	.14	.16
COND	.58	.27	.12	.07	.09	.03	.13	.08	.09	.14	.12	.16
TURB	.18	2.57	.90	129.38	250.94	1.00	2.40	127.52	.83	1.35	.47	47.05
PH	3.54	.12	.91	1.25	15.74	.33	.72	4.61	1.41	1.93	27.83	5.31
DO	112.47	1.02	1.80	2.55	40.22	1.03	1.09	.84	2.07	31.26	19.09	19.40
AMO	23.55	1.56	2.97	1.69	2.22		188.73	62.07	1.00	302.83	25.58	55.65
NITRI	1.47	3.58	.56	.71	.31		1.21	.63	1.14	.67	2.17	1.13
NITRA	.88	.61	84.44	1.00	2.00		.72	.88	1.00	1.08	.67	8.48
PHOS	1.30	1.22	1.17	.50	1.40	.02	2.92	1.40	2.25	6.00	4.33	2.05

The approach taken in this study was to compute statistics of the data that summarized the variable values in some fashion and represented the collective behavior of the data set during each period. Included in this set of statistics was the correlation matrix of the variables. It was noted that pairs of variables that have low linear correlation may yet be highly nonlinearly associated. The test hypothesis was that the theoretical cross-correlation coefficient of the i th and j th variables were the same, i.e., $r_1(i,j) = \tau_2(i,j) = \tau(i,j)$. The subscript 1 stands for the 1972-1978 data while subscript 2 stands for the 1979-1983 data. The variable u is the test statistics and is given by:

$$u = (z_1 - z_2)/((n_1 - 3)^{-1} + (n_2 - 3)^{-1})^{1/2} \qquad (4.1)$$

$$z_1 = 0.5\ (\log_e(1 + r_1) - \log_e(1-r_1)) \qquad (4.2)$$

$$z_2 = 0.5\ (\log_e(1 + r_2) - \log_e(1-r_2)) \qquad (4.3)$$

Variables $r_1(i,j,)$ and $r_2(i,j)$ are the sample cross correlation coefficients; the arguments i and j have been dropped in the equation above for clarity. The variable u is normally distributed (Hald, 1952), p 610) with zero mean and unit variance. If the absolute value of u is smaller than say, 1.96, then the hypothesis that there is no significant difference between the pair of variables cannot be rejected at the 5% level of significance.

Discussion

Table 4. shows the sample statistics for the Before and After data. The sample size for the Before data is 2096 while that for the After data is 1343. Since the data were not collected under controlled and noncontrolled situations (i.e., with the old and the new instrumentation) care must be taken in interpreting the above statistics and others that may be derived from the data.

The only variable that appeared to be unaffected by a change in instrumentation was turbidity: all of the statistics were not significantly different at the 5% level. The maximum temperature of 59.8 ^{o}C (139.64 ^{o}F) may be a possible outlier. Apart from this, only the skewness appears to be significantly different in the case of temperature. Salinity and conductivity appeared to be significantly different in all statistics but the mean.

Table 5 shows the correlation matrix, computed over time and space, for the five variables considered earlier. The matrix reflects the linear association between pairs of the variables. The fourth and fifth columns of Table 5 are entries for the t-values for the Before and After cross correlations, respectively. Using the above criterion it was observed that, for the Before data, only the temparature - depth, turbidity - salinity, and conductivity - depth pairs had nonsignificant correlations. For the After data the salinity - depth, conductivity-depth, temperature-salinity, and temperature - conductivity pairs had nonsignificant correlations.

Table 4. Sample Statistics of Before and After Data

TOTAL OBSERVATIONS(1972-78) : 2069

	SALT	COND	TEMP	TURB
N OF CASES	2069	2022	2069	2069
MINIMUM	0.770	1.400	0.420	0.120
MAXIMUM	58.000	60.250	59.800	7.900
MEAN	32.886	48.245	25.329	0.968
STANDARD DEV	4.651	7.610	4.717	0.730
STD. ERROR	0.102	0.169	0.104	0.016
SKEWNESS	-2.451	-1.617	-0.524	3.356

TOTAL OBSERVATIONS(1979-83) : 1343

	SALT	COND	TEMP	TURB
N OF CASES	1343	1343	1343	1343
MINIMUM	0.000	0.100	0.960	0.000
MAXIMUM	42.000	60.180	40.600	8.800
MEAN	30.514	46.481	26.163	1.002
STANDAR DEV	9.175	12.939	4.425	0.838
STD. ERROR	0.250	0.353	0.121	0.023
SKEWNESS	-1.593	-1.774	-0.986	3.956

Table 5. Pearson Cross-Correlation Matrix

(1972-1978 DATA , 2022 OBSERVATIONS)

	DEPTH	SALT	COND	TEMP	TURB
DEPTH	1.000				
SALT	-0.054	1.000			
COND	0.020	0.816	1.000		
TEMP	0.016	0.042	0.360	1.000	
TURB	0.184	0.016	-0.080	-0.096	1.000

(1979-1983 DATA , 1343 OBSERVATIONS)

DEPTH	1.000				
SALT	0.019	1.000			
COND	-0.026	0.985	1.000		
TEMP	-0.063	-0.015	0.034	1.000	
TURB	0.089	-0.214	-0.205	-0.101	1.000

Four of the ten variable pairs had significant correlations for the Before and the After data. Column six shows that a significant difference existed between the Before and the After data for seven of the ten variable pairs. However, such statistical differences could also stem from sources other than change in instrumentation. The three pairs that did not show significant difference are potentially more informative since these will tend to indicate that neither natural variations (climatic) nor instrumentation changes were significant. Temperature occurred twice while the other variables occurred once each as members of the three-pair group.

The second and third columns of Table 6 are the Before and After cross-correlations for the variable pairs that are identified in the first column. Since some of these cross correlations are low, it was necessary to test for the hypothesis that they were significantly different from zero. The test statistic is:

$$t = (r\sqrt{f})/\sqrt{(1-r^2)} \qquad f = N - 2 \qquad (4.4)$$

where N is the number of records.

If the t - value corresponding to a given value of r was smaller than say the 95% fractile, then the two variables were not significantly correlated. The f values for both Before and After data were each greater than 1000. Therefore the critical value of t(i.e., t_{cr}) at the 95% fractile is 1.545. Hence there was no definite pattern that would enable me to surmise that a particular variable was consistently unaffected by instrument change.

5.0 HOMOGENEOUS WATER QUALITY REGIONS

The objective was to divide the Biscayne Bay into homogeneous water quality regions and to investigate the possibility of reducing the number of sampling stations.

Description of Data

A program, CLUSTER.FOR, was written to process the original data set for the period 1979-1984. The latter segment of the data set was selected for this analysis because it reflected the current sampling stations, which were to be clustered, and the variables which were currently being sampled. The objective was to group the stations into a number classes such that stations within classes were similar in the same respect.

Table 6. Cross correlations for variable pairs

Variable Pairs	Corr-Values Before	Corr-Values After	T-Values Before	T-Values After	Statistics (u)
Salt-Depth	0.054	0.019	-2.431	0.696	-2.073
Cond-Depth	0.020	0.026	0.899	0.952	1.306
Temp-Depth	0.016	0.063	0.719	-2.312	2.244
Turb-Depth	0.184	0.089	8.413	3.272	2.750
Cond-Salt	0.816	0.985	63.445	209.038	-36.836
Temp-Salt	0.042	0.015	1.889	0.549	1.618
Turb-Salt	0.016	0.214	0.719	-8.022	6.623
Temp-Cond	0.360	0.034	17.343	1.246	9.731
Turb-Cond	0.080	0.205	-3.607	-7.670	3.626
Turb-Temp	0.96	0.101	-4.335	-3.718	0.143

The program computed the mean value, over time, for each water quality variable sampled at each station at a depth of 0.2 meters or less. Thus, the resulting reduced data are for 'surface' samples. These means were readily computed for other depth limits or even further averaged over depth of measurement. Recall that the analyses of Section 3 showed no statistically significant difference between measurements for the five depth categories. The reduced data are given in Table 7 below. The data were stored in the file CLUSTER.DAT and contained the following variables: depth, salinity, conductivity, water temperature, turbidity, pH and dissolved oxygen.

Methods

Cluster analysis is a multivariate procedure for detecting natural groupings in a data set. As per the scope of work, I grouped the sampling stations (cases) and the variables in each case to see if any stations could be dropped from the sampling program without losing information for understanding, for example, the recycling of nutrients in the

Table 7. Data for Cluster Analysis

STATION	DEPTH	SALT	COND	TEMP	TURB	PH	DO
2	0.03	7.28	12.27	26.52	1.13	7.79	4.89
4	0.03	17.46	21.29	27.15	1.68	7.62	3.61
6	0.04	17.87	28.62	26.88	1.10.	8.05	5.36
7	0.01	26.44	41.82	25.57	1.81	7.54	3.04
8	0.04	25.36	40.48	26.75	2.28	7.45	2.59
11	0.03	27.66	37.04	26.24	1.09	8.27	6.60
15	0.03	33.17	50.74	25.72	0.79	8.36	6.17
18	0.02	35.92	54.33	25.75	1.40	8.42	6.22
19	0.02	35.83	54.15	25.88	0.81	8.38	5.98
21	0.04	26.93	42.08	26.12	0.72	8.25	6.33
25	0.02	32.76	49.98	25.68	0.82	8.11	6.18
28	0.02	36.05	54.39	25.72	1.24	8.41	6.14
29	0.03	35.95	54.37	26.26	0.81	8.13	6.23
30	0.10	33.12	50.70	21.30	0.59	8.56	6.39
31	0.04	27.02	41.28	26.53	0.86	8.37	6.23
35	0.03	32.92	50.11	24.84	0.81	8.08	5.91
38	0.03	36.15	54.56	26.06	1.18	8.41	6.15
39	0.02	36.49	54.89	26.08	0.75	8.40	6.10
51	0.02	30.10	46.57	26.05	0.85	8.34	6.12
55	0.03	34.31	52.25	25.53	0.86	8.37	6.17
58	0.02	36.28	54.75	25.94	1.11	8.41	6.20
61	0.03	31.50	48.55	25.79	0.80	8.37	5.92
65	0.03	34.48	52.47	25.59	0.86	8.36	6.06
68	0.03	35.78	54.09	26.11	1.10	8.39	6.15
71	0.04	32.29	49.44	25.87	0.69	8.37	6.01
75	0.03	34.45	52.43	25.67	0.89	8.37	6.02
78	0.03	35.57	53.84	26.07	0.98	8.37	6.16
81	0.04	33.04	50.45	25.83	0.63	8.38	6.02
84	0.00	36.90	55.40	25.60	0.86	8.39	6.66
85	0.04	34.19	52.16	26.07	0.70	8.36	6.00
88	0.03	35.67	54.11	26.97	0.96	8.38	6.30
92	0.02	32.96	50.34	25.33	0.61	8.36	5.60
96	0.03	34.55	52.57	25.77	0.74	8.33	5.98

UNITS:dpth (m), salinity (ppt), conductivity (mmhos/cm^2,)
Temperature (C), Turbidity (NTU), dissolved oxygen (ppm)

micro-ecosystem around the station. Cluster analysis was therefore, an appropriate procedure to this end.

The set of data contain variables that had different units of measurement. The variables were therefore standardized (reduced to mean zero and unit variance) in order to remove the scale effects. This was done despite the possibility that the standardizations may have diluted the differnces between groups. Further, the high correlation between the conductivity and salinity required me to select a clustering algorithm that did not assume that the variables were uncorrelated. Two methods, the Single-Linkage and the K-Means, were used.

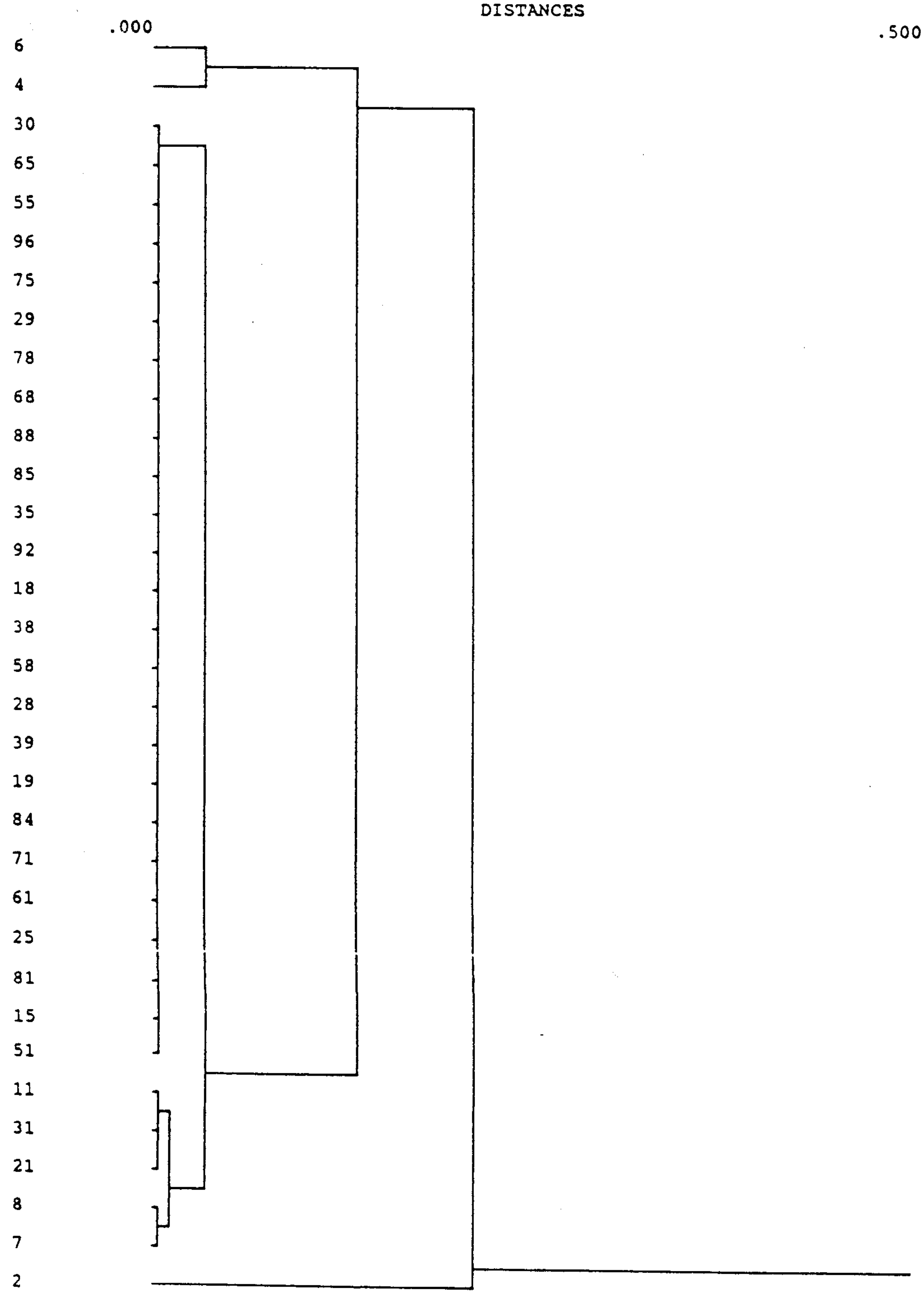
Single-Linkage Method: This method forms clusters by combining groups with the shortest distance between their centroids. The distance metric used is the PEARSON metric which uses $(1 - r_{ij})$ as the distance index where r_{ij} is the correlation between the i th and the j th objects being clustered. For this study the object was either a sampling station or a sampled variable. Recall that the correlation coefficient is the standardized form of the covariance between two objects. The output shown below as Figure 2 is a branching tree of the variables and stations, respectively, using the data of Table 7.

K-Means Method: This method splits the set of objects into a given number of clusters by maximizing the between-cluster relative to the within-cluster variation. A value of K=3 was selected based on an inspection of Figure 2. Table 8 shows the result of this analysis. Summary statistics for all three clusters are given with respect to the six variables used. Sample statistics, also with respect to the variables, are given for each cluster. The statistics were computed over the membership of the cluster. Table 9. shows similar information for the case k=2. These tables provide the basis for the discussion that follows.

Figure 2. Branching Tree of the Clustering Stations

DISTANCE METRIC IS 1-PEARSON CORRELATION COEFFICIENT
LINKAGE METHOD IS NEAREST NEIGHBOR

TREE DIAGRAM



Discussion

An inspection of Figure 2 shows that at a distance cut off of about 0.03 three clusters may be discerned. Stations 4 and 6 belong to one cluster, Station 2 forms a singleton,and the balance of the stations make up the third cluster. Using the K-Mean algorithm with K=3, Table 8 shows that the membership of the three clusters is rearranged somewhat. Cluster 1 now includes stations 2, 4,and 6 while Cluster 3 now includes Stations 7, 8, 11, 21, 31, and 51. The rest of the stations belong to Cluster 2. An inspection of Figure 1 shows that Cluster-1 stations were all located on the canals -- Station 2 on the Moody Canal, Station 4 on Military Canal, and Station 6 on the Mowry Canal. Similarly, the Cluster-3 stations were located on the Florida City Canal (Stations 7 and 8) and close to the coastline (Stations 11, 21, and 51) along the axis of the Moody, Military, Mowry, and Florida City canals, respectively. Table 9 shows that when the analysis was repeated for two clusters only, all of the members of Clusters 1 and 3 above, except station 51, were in one cluster while the rest were in the second cluster. The membership of Cluster 2 (Table 8) was further examined by obtaining a contour plot (Figure 3) of distance values. The station latitude and longitude constituted the plotting axes. The distance values were categorized as shown in the legend of Figure 3. It is observed that the centroid of this cluster was around stations 65 and 75 since they had distance values close to zero. The following within cluster groups may be identified.

Group	Symbol	Membership
1	'+`	15, 18, 19, 28, 29
2	'*`	25, 35, 38, 58, 39
3	'+`	68, 78, 88
4	'.`	55, 65, 75, 85, 96
5	'=`	30, 61, 71, 84
6	'*`	81, 92

The above table provides a basis for deleting stations.

Table 8. Summary Statistics for Three Cluster Case

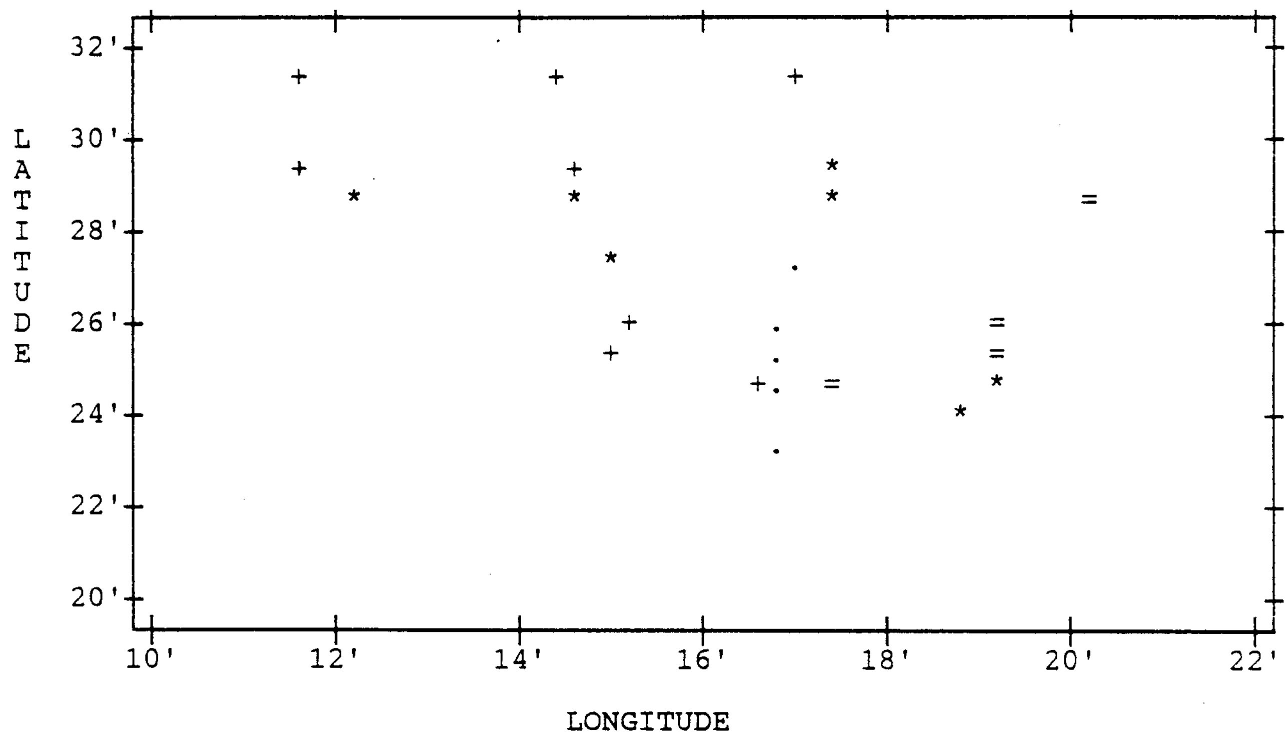
VARIABLE	BETWEEN SS	DF	WITHIN SS	DF	F-RATIO	PROB
SALT	1235.742	2	140.206	30	132.206	0.000
COND	2973.186	2	277.109	30	160.940	0.000
TEMP	4.805	2	24.043	30	2.998	0.065
TURB	1.078	2	3.170	30	5.102	0.012
PH	1.082	2	1.237	30	13.115	0.000
DO	9.055	2	19.129	30	7.100	0.003

MEMBERS			STATISTICS				
CLUST	STA	DIST	VARIABLE	MINIMUM	MEAN	MAXIMUM	SD
1	2	4.47	SALT	7.28	14.20	17.87	4.90
	4	1.43	COND	12.27	20.73	28.00	6.69
	6	3.57	TEMP	26.52	26.85	27.00	0.26
			TURB	1.10	1.30	18.00	0.27
			PH	7.62	7.82	8.05	0.18
			DO	3.61	4.62	5.36	0.74
2	15	0.94	SALT	31.50	34.60	36.90	1.52
	18	0.93	COND	48.55	52.54	55.40	2.00
	19	0.83	TEMP	21.30	25.64	26.97	0.98
	25	1.29	TURB	0.59	0.87	1.40	0.20
	28	0.97	PH	8.08	8.35	8.56	0.10
	29	0.97	DO	5.60	6.11	6.66	0.19
	30	2.03					
	35	1.26					
	38	1.06					
	39	1.24					
	55	0.18					
	58	1.14					
	61	2.07					
	65	0.06					
	68	0.82					
	71	1.58					
	75	0.09					
	78	0.69					
	81	1.07					
	84	1.51					
	85	0.30					
	88	0.95					
	92	1.15					
	96	0.10					
3	7	1.01	SALT	25.36	27.25	30.10	1.45
	8	1.47	COND	37.04	41.55	46.57	2.80
	11	1.94	TEMP	25.57	26.21	26.75	0.37
	21	0.60	TURB	0.72	1.27	2.28	0.58
	31	0.53	PH	7.45	8.04	8.37	0.39
	51	2.40	DO	2.59	5.15	6.60	1.66

Table 9. Summary Statistics for Two Cluster Case

VARIABLE	BETWEEN SS	DF	WITHIN SS	DF	F-RATIO	PROB
SALT	934.086	1	441.855	31	65.534	0.000
COND	2233.159	1	1017.141	31	68.061	0.000
TEMP	3.983	1	24.865	31	4.966	0.033
TURB	1.283	1	2.965	31	13.417	0.001
PH	1.146	1	1.173	31	30.302	0.000
DO	9.966	1	18.218	31	16.958	0.000

MEMBERS			STATISTICS				
CLUST	STA	DIST	VARIABLE	MINIMUM	MEAN	MAXIMUM	SD
1	2	10.42	SALT	7.28	22.00	27.66	6.77
	4	5.20	COND	12.27	33.11	42.08	10.53
	6	2.51	TEMP	25.57	26.47	27.15	0.46
	7	4.08	TURB	0.72	1.33	2.28	0.50
	8	3.46	PH	7.45	7.92	8.37	0.34
	11	2.91	DO	2.59	4.83	6.60	1.47
	21	4.23					
	31	3.96					
2	15	0.82	SALT	30.10	34.42	36.90	1.73
	18	1.05	COND	46.57	52.31	55.40	2.28
	19	0.95	TEMP	21.30	25.66	26.97	0.96
	25	1.17	TURB	0.59	0.87	1.40	0.20
	28	1.09	PH	8.08	8.35	8.56	0.10
	29	1.08	DO	5.60	6.11	6.66	0.19
	30	1.98					
	35	1.14					
	38	1.18					
	39	1.36					
	51	2.94					
	55	0.08					
	58	1.26					
	61	1.94					
	65	0.08					
	68	0.94					
	71	1.46					
	75	0.07					
	78	0.80					
	81	0.95					
	84	1.64					
	85	0.22					
	88	1.05					
	92	1.04					
	96	0.15					



LEGEND:						
	.	....		Distance	<	0.5
	+	....	0.5 <	Distance	<	1.0
	*	....	1.0 <	Distance	<	1.5
	=	....		Distance	>	1.5

6.0 QUALITY IMPACT OF CANAL DISCHARGE INTO BAY

The objective was to determine whether canal discharge into the Biscayne Bay influences water quality and how far offshore is this effect, if any, noticeable.

Description of Data

The manner in which the water quality data and the Canal discharge data have been combined into one data set contained in file FLOWQUAL.DAT was described in Section 3. The stations of interest are those along the axis of the Moody Canal (i.e., 2, 11, 12, 13, 14, 15, 16, 18, 19) and those along the axis of the Mowry Canal (i.e. 6, 31, 32, 33, 34, 35, 36, 38, 39). The water quality variables used were conductivity, salinity, temperature, turbidity, and pH.

To be manageable the measured values of the variables were converted into categorical data. As an initial analysis, the data was split into two categories. The threshold values for the variables were assumed as follows: depth 1.0 m, salinity 34 ppt, conductivity 47.5 mmhos/cm^2, water temperature 25 ^oC, turbidity 1.5 NTU, pH 7.0, and canal discharge 1.00 cfs (0.028 m^3/sec). Four categories were established for each variable.

Category 1 corresponds to the situation when the discharge is above the threshold of 1.00 cfs and the variable had value above the assumed threshold;
Category 2 corresponds to the situation when the discharge is above 1.00 cfs and the variable is below its threshold;
Category 3 corresponds to the situation when discharge is below 1.00 cfs and the variable is above its threshold; and
Category 4 corresponds to the situation when discharge is below 1.00 cfs and the variable is below its threshold value.

A new variable, FLOWPARA, was thus defined as the categorical variable which assumes a value of 1, 2, 3, or 4. A FORTRAN program, CAT.FOR was written to convert the measured values into categorical data. The program also obtains the frequency of each category for a given station - variable - canal combination. The counting process was done with respect to the sampling dates. Those frequencies were obtained for each day (up to 4 days) before each quality sampling date. Table 10 shows the output from CAT.FOR for conductivity. The output for all of the variables was stored in the file TABLE.DAT and was used as the input data for the Contingency Analysis.

Methods

The TABULATE command in the TABLES module of the SYSTAT microcomputer statistical package was used to construct a multiway contigency table. Given the data of Table 10, the contigency table was formed from the cell frequencies and constitutes a four-way table since the frequencies are classified by the four categorical indicies FLOWPARA, STATION, CANAL, and PARA. The index PARA represents the water-quality variable.

Reading of the table is facilitated by conditioning initially on the canal index and then by the water-quality variable index thus reducing the original four-way table into a set two-way marginal tables. This generates more tables although each of the resulting tables is much simpler to read and interpret. Table 11 contains a sample of such tables for Moody Canal and each of the four water-quality variables using canal discharge that was measured on the day that the Bay water quality was sampled.

Table 10. Frequency of Categorized Conductivity Data

FLOWPARA	STA	CANAL	FREQUENCY 0	1	2	3	4
2	2	1	21	19	19	21	22
4	2	1	21	23	23	21	20
2	11	1	22	21	20	22	23
3	11	1	3	4	3	4	3
4	11	1	24	25	26	24	23
1	15	1	9	10	8	9	9
2	15	1	12	9	11	11	12
3	15	1	11	10	12	11	11
4	15	1	16	19	17	17	16
1	18	1	16	15	13	15	15
2	18	1	4	3	5	4	5
3	18	1	23	24	26	24	24
4	18	1	4	5	3	4	3
1	19	1	17	15	14	15	17
2	19	1	3	3	3	4	4
3	19	1	22	24	25	24	22
4	19	1	2	2	2	1	1
2	6	2	39	35	38	38	39
3	6	2	6	6	6	6	6
4	6	2	7	11	8	8	7
1	31	2	9	7	6	6	7
2	31	2	63	63	63	64	66
3	31	2	17	19	20	20	19
4	31	2	16	16	16	15	13
1	32	2	5	5	2	2	3
2	32	2	12	13	12	13	15
3	32	2	4	4	7	7	6
4	32	2	4	3	4	3	1
1	33	2	8	8	5	5	7
2	33	2	9	10	9	10	11
3	33	2	5	5	8	8	6
4	33	2	3	2	3	2	1
1	34	2	15	16	12	12	15
2	34	2	2	2	2	3	3
3	34	2	9	8	12	12	9
4	34	2	2	2	2	1	1
1	35	2	30	29	26	27	30
2	35	2	37	37	39	38	38
3	35	2	21	22	25	24	21
4	35	2	6	6	4	5	5
1	36	2	17	18	14	15	18
3	36	2	12	11	15	14	11
1	38	2	37	34	36	36	37
2	38	2	14	14	15	15	14
3	38	2	21	24	22	22	21
4	38	2	2	2	1	1	2
1	39	2	34	30	33	33	34
2	39	2	8	8	9	9	9
3	39	2	16	20	17	17	16
4	39	2	2	2	1	1	1

* Number of days before water quality sampling

Table 11. Table of Station (rows) by FLOWPARA (columns)

CANAL = MOODY
PARA = SALINITY

STATION	1	2	3	4	TOTAL
2	.00	61.90	.00	38.10	100.00
11	2.00	56.00	6.00	36.00	100.00
15	25.00	31.25	16.67	27.08	100.00
18	46.81	8.51	36.17	8.51	100.00
19	52.27	6.82	36.36	4.55	100.00
TOTAL	25.11	32.90	19.05	22.94	100.00

PARA = CONDUCTIVITY

STATION	1	2	3	4	TOTAL
2	.00	61.90	4.76	33.33	100.00
11	10.00	48.00	12.00	30.00	100.00
15	41.67	14.58	25.00	18.75	100.00
18	53.19	2.13	34.04	10.64	100.00
19	59.09	.00	34.09	6.82	100.00
TOTAL	32.90	25.11	22.08	19.91	100.00

PARA = TEMPERATURE

STATION	1	2	3	4	TOTAL
2	52.38	9.52	19.05	19.05	100.00
11	42.00	16.00	18.00	24.00	100.00
15	41.67	14.58	20.83	22.92	100.00
18	42.55	12.77	21.28	23.40	100.00
19	43.18	15.91	18.18	22.73	100.00
TOTAL	44.16	13.85	19.48	22.51	100.00

PARA = TURBIDITY

STATION	1	2	3	4	TOTAL
2	11.90	50.00	16.67	21.43	100.00
11	10.00	48.00	4.00	38.00	100.00
15	2.08	54.17	2.08	41.67	100.00
18	14.89	40.43	10.64	34.04	100.00
19	2.27	56.82	2.27	38.64	100.00
TOTAL	8.23	49.78	6.93	35.06	100.00

Table 12. Contingency Table of Station by FLOWPARA

CANAL = Moody
PARA = Salinity

FLOWPARA	1	2	3	4	TOTAL
STATION					
2	.00	59.52	.00	40.48	100.00
11	2.00	54.00	6.00	38.00	100.00
15	22.92	31.25	18.75	27.08	100.00
18	40.43	12.77	42.55	4.26	100.00
19	45.45	9.09	43.18	2.27	100.00
TOTAL	22.08	33.33	22.08	22.51	100.00

PARA = CONDUCTIVITY

FLOWPARA	1	2	3	4	TOTAL
STATION					
2	.00	59.52	4.76	35.71	100.00
11	8.00	48.00	14.00	30.00	100.00
15	33.33	20.83	33.33	12.50	100.00
18	44.68	8.51	42.55	4.26	100.00
19	50.00	4.55	43.18	2.27	100.00
TOTAL	27.27	28.14	27.71	16.88	100.00

PARA = TEMPERATURE

FLOWPARA	1	2	3	4	TOTAL
STATION					
2	50.00	9.52	21.43	19.05	100.00
11	42.00	14.00	18.00	26.00	100.00
15	39.58	14.58	22.92	22.92	100.00
18	40.43	12.77	23.40	23.40	100.00
19	40.91	13.64	20.45	25.00	100.00
TOTAL	42.42	12.99	21.21	23.38	100.00

PARA = TURBIDITY

FLOWPARA	1	2	3	4	TOTAL
STATION					
2	11.90	47.62	16.67	23.81	100.00
11	8.00	48.00	6.00	38.00	100.00
15	4.17	50.00	0.00	45.83	100.00
18	12.77	40.43	12.77	34.04	100.00
19	4.55	50.00	0.00	45.45	100.00
TOTAL	8.23	47.19	6.93	37.66	100.00

Table 12 also contains such tables but for the case of Canal discharge, two days before Bay sampling. Note that the entries in the tables are row percents rather than absolute frequencies. This was done to facilitate inferences from the tables. Thus, the entry f_{ijk} is the percent of time that variable k fell into category j at location (station) i.

Different types of statistical analyses (models) may be applied to the contingency table and corresponding statistics computed. These include testing of hypothesis about the homogeneity of the data, row effects, column effects, the interaction between the indices, and the order of these interaction; and Log-linear modeling for predicting expected cell frequencies. Because of the coarse nature of the categorization of the data, however, the discussion below is limited to examining the pattern of row-wise and column-wise frequencies.

Discussion

The first point to make is that the thresholds, on which the categorization of the variables was based, are arbitrary. Thus inferences on the patterns of percent frequencies must be made on a relative basis. Also, as observed earlier, in order to account for possible lagged response of the Bay to Canal discharge, discharges that occured up to four days before bay quality sampling were taken into consideration. The assumption was made, however, that the full effect (dilution/pollution) of the Canal discharge was felt at furthest sampling station from the outlet. The contingency tables were constructed for all five discharge situations; only two are included in this report (Tables 11 and 12). Observed patterns may be explained in the context of the difinition of the categories made in page 24.

The salinity and conductivity sections in Table 11 show similar patterns. Table 11 was constructed with Canal discharge that was measured the same day as the Bay quality sample. The percent frequencies were observed to increase with distance from the coast when the salinity/conductivity value was less than the threshold. In contrast, temperature showed a fairly uniform distribution of percent frequencies while for turbidity the picture was mixed for all categories.

7.0 FACTOR ANALYSIS OF WATER QUALITY VARIABLES

The objectives were to combine the sampled variables into subgroups, represented by factors, which convey the essential information contained in the membership of the subgroup and to identify the variables with high variability so as to recommend sampling frequency for those variables.

Decription of Data

The same data set (CLUSTER.DAT) used in performing the Cluster Analysis was used to perform the Factor Analysis of the Bay water quality data. Recall that data set was obtained from the original 1979-1984 data. It contains the mean, over time and for sample depths less than or equal to 0.2m, of the following variables; salinity,c onductivity, Temperature, turbidity, pH and dissolved oxygen.

Methods

The method of Factor Analysis was applied to construct factors that were made up of subgroups of the original set of water quality variables. That original set of variables may or may not be correlated. The final set of factors were uncorrelated and dimensionless linear combinations of members of their respective subgroups.

The FACTOR module of the SYSTAT Microcomputer Statistical package was used to perform the analysis. The correlation matrix of the water-quality variables was chosen as the matrix to be factored. The Principal Components submodule was used to construct the initial set of factors. From this set and following conventional practice, factors with eigenvalues greater than or equal to one were retained. Thus if the water quality variables are represented by $\{x_i\}$, i=1,6, the score for the j th factor is given by:

$$\Phi_j = \beta_{j1}x_1 + \beta_{j2}x_2 + \beta_{j3}x_3 + \beta_{j4}x_4 + \beta_{j5}x_5 + \beta_{j6}x_6 \qquad (7.1)$$

where some of the variables will not contribute to the score and the β's are the factor score coefficients.

FACTOR standardizes the original variables before factoring in order to remove scale effects. Because of this standardization, the variance of each variable is one. This unit variance is comprised of the communality, due to characteristics common to all the variables, and the specificity, due to characteristics unique to the variable. The factor loading of a variable is the correlation between the standardized variable and the common factor.

The Varimax method was used to rotate the common factors. Rotation methods attempt to select the factors so that some of the loadings are close to plus or minus one and the remaining loadings are close to zero. Ideally each variable should have a high loading on only one factor.

Discussion

Table 13 contains selected output from the FACTOR module. An examination of the correlation matrix showed that the correlations were much higher than in the initial correlation matrix (Table 6) when individual values rather than means were used. High correlations existed between SALT and COND, PH and SALT, PH and COND, PH and TURB, and DO and TURB.

The eigenvalues (latent roots) obtained were:

Factor	:	1	2	3	4	5	6
Eigenvalue	:	3.88	1.01	0.83	0.19	0.07	0.01

Table 13 also contains the initial and rotated factor loadings, the factor score coefficients of the rotated loadings, and the percentage of the total variance explained by each factor, for the two factors with an eigenvalue grater than or equal to one. The two factor - rotated loadings show that the first component had TURB, DO, and PH as the important variables while the second component had SALT and COND as the important variables. TEMP did not have a strong showing in either component. This supports the observation, in Tables 8 and 9, that showed PROB = 0.065, i.e., that the contribution of temperature in the clusters formation was not significant at the 5% level.

Further insight may be gained from the communality and specificity computed for each variable:

Variable	PH	DO	COND	SALT	TURB	TEMP
Communality :	0.91	0.89	0.99	0.99	0.89	0.23
Specificity :	0.09	0.11	0.01	0.01	0.09	0.77

These statistics show that, except for the temperature, the communality of each of the variables was very high indicating that the variance in the measured values was explained by common characteristics. The variance in the temperature measurements appears to be explained by characeristics which were not shared by the other variables.

Table 13. Factor Analysis Results

Correlation Matrix

	SALT	COND	TEMP	TURB	PH	DO
SALT	1.000					
COND	0.990	1.000				
TEMP	-0.310	-0.329	1.000			
TURB	-0.382	-0.388	0.368	1.000		
PH	0.689	0.676	-0.359	-0.759	1.000	
DO	0.566	0.543	-0.261	-0.808	0.913	1.00

	Initial Factor Loadings		Rotated Factor Loadings		Factor Score Coefficients	
	1	2	1	2	1	2
DO	0.880	-0.337	0.886	0.321	0.389	-0.104
PH	0.938	-0.166	0.818	0.489	0.290	0.034
TURB	-0.778	0.536	-0.939	-0.104	-0.498	0.269
SALT	0.837	0.536	0.282	0.953	-0.184	0.541
COND	0.832	0.541	0.275	0.954	-0.188	0.544
TEMP	-0.481	0.061	-0.403	-0.268	-0.133	-0.035
Variance Explained:	3.883	1.012	2.652	2.243		
Percent Explained:	64.72	16.88	44.21	37.39		

8.0 DETERMINING SAMPLING FREQUENCY

The objectives were to investigate possible trends in the data sets and to determine the optimal sampling interval based on statistical inference methods.

Description of Data

The starting point of the analysis to obtain the sampling frequency to be used by Park personnel was the original data file, QUAL.DAT, containing all 5166 records with 12 variables and the sampling depth per record. The file DATE.DAT contained the sampling dates and the beginning and ending serial number of the stations that were sampled on the corresponding date. The program SEQ'.FOR combined the above two data sets and in the process abstracted the time-ordered values of a given variable sampled at a given station. The variable used in this section was the conductivity. The program excluded those sampling days for which no data were collected from the station of interest. The output was stored in file DATA11.DAT for station 11, DATA04.DAT for station 04 and so on. The output was the conductivity averaged over the sampled depths for the sampling date.

The program SE.FOR assigned the sampled dates in DATA11.DAT, for example, into a corresponding interval of one month duration. Thus, some intervals contain more than one sampling day while others contain none. The output from this program was the depth-averaged conductivity now averaged over the number of sampling days within the month. The output was stored, for station 11 for example, in file S11.DAT and consisted of the month order and mean conductivity for the month. Entries of 99.99 corresponded to no samples taken on any day within that month.

Methods

The Kendall (1970) Rank Correlation method was applied to meet the objectives. The Kendall test is ordinarily used to detect seasonalities. A variation of this test was used by Hirsch et al. (1982) to test for trends in a hydrologic time series. By considering the rank correlation between the rank and the time order of the set $\{y_i\}$, i=1,n of observations, the rank score, S, is written as

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(y_j - y_k) \tag{8.1}$$

where n is the sample size and

$$\operatorname{sgn}(m) = \begin{cases} 1 & \text{for } m<0 \\ 0 & \text{for } m=0 \\ -1 & \text{for } m>0 \end{cases} \tag{8.2}$$

The rank correlation coefficient is given by

$$\tau = 2S/(n(n-1)) \tag{8.3}$$

Testing the significance of τ is equivalent to testing the hypothesis that the sequence of values is independent and identically distributed against the alternate hypothesis that the sequence is not. Under the null hypothesis τ and hence S are normally distributed in the limit as n appraoches infinity and for all practical purposes for $n \geq 10$. It has zero mean and standard deviation, σ:

$$\sigma = [n(n-1)(2n+5) - \Sigma t(t-1)(2t+5)]/18 \tag{8.4}$$

where t is the number of observations involved in a tie. Let s* be an observed value of S, then the reduced variate is $u= s^* /\sigma$. If u lies in the tails of the standardized normal distribution, at an assumed level of significance, then one rejects the hypothesis that successive values of the series are independent. In such a case each observation provides new information about the variable and so the sampling interval should be maintained.

Discussion

The above method was applied to stations 4, 11, 18, 35, and 92 which were representative of the distribution of stations and were also among the most sampled. Program SS.FOR was written to accomplish the analysis. The file S04.DAT ,for example, was used as input for the program. First, the program partitioned the data file into time segments with uninterupted monthly data. It then computed, for each segment, the total score, Kendall's rank-correlation coefficient, the standard deviation of the score, and the reduced variate. Table 14 gives these results for the five stations listed above.

The last column of Table 14 contains the probability, P, that the observed score or its reduced variate will be attained or exceeded in absolute value. The entries in this column, for sample sizes less than 10, were taken from a table given by Kendall (1970, p 173). The normal table was used otherwise. Only 5 of the 38 analyzed analyzed gave P values less than the significance level of 0.05 assumed for this study. Thus, one needs not to reject the hypothesis of independence of the monthly observations. It is noteworthy that none of the segments with sample sizes greater than 10 had a value of P less than 0.05.

The above analysis was repeated for sampling intervals of 2, 3, and 4 months using the data segments in Table 14 that had 12 or more consecutively sampled months. The larger sampling intervals were obtained by deleting intermediate values from the Table 14 data. Table 15 gives the results for this case and shows that no P values were less than 0.05. The mean P values for the sampling intervals (Δt) were:

Δt	1	2	3	4 (months)
P	0.48	0.65	0.60	0.61

These mean values all indicated independence between observations at the respective sampling intervals and showed no significant change in the degree of independence with increasing sample size. When examined by station, the P values showed no desernable pattern over the sampling intervals.

Table 14. Results of Rank Correlation Analysis for Monthly Sampling Interval

Sta	Time segment		Sample size	Total score	Kendall Tau	Std dev	Reduced variate	P
4	78273	79090	6	-11.00	0.73	5.32	-2.25	0.06
4	79120	81059	22	-5.00	0.02	35.46	0.17	0.87
4	81090	81334	8	10.00	0.36	8.08	1.11	0.27
4	81365	82181	6	5.00	0.33	5.32	0.75	0.47
4	83120	83365	8	6.00	0.21	8.08	0.62	0.55
11	72091	73090	12	-12.00	0.18	14.58	0.89	0.37
11	75181	76031	7	3.00	0.14	6.66	0.30	0.77
11	76244	77120	8	-16.00	0.57	8.08	-2.10	0.06
11	77212	78059	7	7.00	0.33	6.66	0.90	0.38
11	78090	79090	12	24.00	0.36	14.58	1.58	0.11
11	79120	81059	22	-61.00	0.26	35.46	-1.75	0.08
11	81090	81334	8	12.00	0.43	8.08	1.36	0.18
11	81365	82181	6	1.00	0.07	5.32	0.00	1.00
11	83120	83334	7	9.00	0.43	6.66	1.20	0.24
18	75181	76031	7	15.00	0.71	6.66	2.10	0.03
18	76244	77120	8	2.00	0.07	8.08	0.12	0.90
18	77243	78059	6	13.00	0.87	5.32	2.25	0.02
18	78181	81059	32	85.00	0.17	61.67	1.36	0.17
18	81090	81334	8	15.00	0.54	8.08	1.73	0.09
18	81365	82181	6	-5.00	0.33	5.32	-1.13	0.47
18	83120	83334	7	15.00	0.71	6.66	2.10	0.03
35	72091	73090	12	2.00	0.03	14.58	0.07	0.94
35	75181	76031	7	13.00	0.62	6.66	1.80	0.07
35	76244	77120	8	0.00	0.00	8.08	0.12	1.00
35	77243	78059	6	15.00	1.00	5.32	2.63	0.00
35	78243	79151	9	-6.00	0.17	9.59	0.73	0.61
35	79181	81059	20	3.00	0.02	30.82	0.06	0.95
35	81090	81334	8	13.00	0.46	8.08	1.48	0.13
35	81365	82181	6	1.00	0.07	5.32	0.00	1.00
35	83120	83365	8	20.00	0.71	8.08	2.35	0.01
92	72091	73090	12	-13.00	0.20	14.58	0.96	0.34
92	75181	76031	7	11.00	0.52	6.66	1.50	0.14
92	76244	77120	8	-2.00	0.07	8.08	0.37	0.90
92	77243	78059	6	11.00	0.73	5.32	1.88	0.06
92	78243	79151	9	-12.00	0.33	9.59	-1.36	0.26
92	79181	81059	20	-22.00	0.12	30.82	0.75	0.45
92	81090	81334	8	12.00	0.43	8.08	1.36	0.18
92	81365	82181	6	-3.00	0.20	5.32	0.75	0.72

P is the probability that the reduced variate will be attained or exceeded in absolute value

Table 15. Results of Rank Correlation Analysis for Different Sampling Intervals

Δt	Sta	Time segment		Sample size	Total score	Kendall Tau	Std dev	Reduced variate	P
1	04	79120	81059	22	-5.00	0.02	35.46	0.17	0.87
	11	72091	73090	12	-12.00	0.18	14.58	0.89	0.37
	11	78090	79090	12	24.00	0.36	14.58	1.58	0.11
	11	79120	81059	22	-61.00	0.26	35.46	-1.75	0.08
	18	78181	81059	32	85.00	0.17	61.67	1.36	0.17
	35	72091	73090	12	2.00	0.03	14.58	0.07	0.94
	35	79181	81059	20	3.00	0.02	30.82	0.06	0.95
	92	72091	73090	12	-13.00	0.20	14.58	0.96	0.34
	92	79181	81059	20	-22.00	0.12	30.82	0.75	0.45
2	04	79120	81031	11	5.00	0.09	12.85	0.31	0.75
	11	72091	73059	6	-1.00	0.07	5.32	0.38	1.00
	11	78090	79059	6	7.00	0.47	5.32	1.13	0.27
	11	79120	81031	11	-23.00	0.42	12.85	-1.87	0.06
	18	78181	81031	16	16.00	0.13	22.21	0.68	0.50
	35	72091	73059	6	1.00	0.07	5.32	0.00	1.00
	35	79181	81031	10	7.00	0.16	11.18	0.54	0.60
	92	72091	73059	6	-3.00	0.20	5.32	0.75	0.72
	92	79181	81031	10	-1.00	0.02	11.18	0.18	1.00
3	04	79120	81059	8	0.00	0.00	8.08	0.12	1.00
	11	72091	73031	4	2.00	0.33	2.94	0.34	0.75
	11	78090	79031	4	4.00	0.67	2.94	1.02	0.34
	11	79120	81059	8	-14.00	0.50	8.08	-1.86	0.10
	18	78181	81031	11	14.00	0.25	12.85	1.01	0.32
	35	72091	73031	4	2.00	0.33	2.94	0.34	0.75
	35	79181	81031	7	-1.00	0.05	6.66	0.30	1.00
	92	72091	73031	4	2.00	0.33	2.94	0.34	0.75
	92	79181	81031	7	-7.00	0.33	6.66	-1.20	0.39
4	04	79120	81031	6	-3.00	0.20	5.32	0.75	0.72
	11	72091	72366	3	1.00	0.33	1.91	0.00	*
	11	78090	78365	3	3.00	1.00	1.91	1.04	*
	11	79120	81031	6	-5.00	0.33	5.32	-1.13	0.47
	18	78181	80335	8	-2.00	0.07	8.08	0.37	0.90
	35	72091	72366	3	1.00	0.33	1.91	0.00	*
	35	79181	80335	5	-4.00	0.40	4.08	-1.22	0.48
	92	72091	72366	3	1.00	0.33	1.91	0.00	*
	92	79181	80335	5	-4.00	0.40	4.08	-1.22	0.48

* No entries for sample size of less than 4 in Kendall's table

Δt is the sampling interval in months

CONCLUSIONS AND RECOMMENDATIONS

An observational study has been performed on a set of water quality data obtained in time and space over Biscayne Bay, Florida. In all, about 131 sampling episodes were carried out over a period of about 12 years.

Data summaries of 11 water quality variables were calculated for all the water quality stations and for all the categories of sampled depths. The basic data were the time ordered samples of these variables. Based on a multivariate analysis of the variances it was concluded that there was no significant variation in the sampled water quality variables with depth. On the average, ammonium, turbidity, and dissolved oxygen were the most variable; pH and nitrate were the next most variable, while salinity and conductivity were the least variable.

Heuristic approaches that rely on standard hypothesis testing were applied to investigate the significance of a 1979 change in techniques for measuring water-quality variables. The cross-correlation matrix of the Before change and that of the After change data were used in this regard in addition to the comparison of the corresponding basic statistics. It was not established that the change was significant at the 5% .

Two clustering methods were applied to the data that were collected between 1979 and 1984. The Single Linkage method provided a dendrogram from which the number of clusters required was determined. The K-Means method, with the number of cluster k=3, was also applied. An additional application of this method for k=2 was made for comparison. The conclusion was that there are basically two broad clusters of stations: those at the mouth of the canals and nearshore and those that were offshore. A secondary analysis of the offshore stations provided a basis for deleting some of those stations without losing valuable information on the microecosystem around the deleted station.

The records of the Moody and Mowry canal discharges into Biscayne Bay were combined with the Bay water-quality data in order to investigate the impacts of such discharges. Thresholds were assumed for the discharge and water-quality variables.

Contingency tables based on categorized canal discharge and water-quality variables were then formulated. Because of the arbitrary choice of thresholds, only relative inferences could be made concerning the pattern of frequencies in the contingency table. Definite trends in the percent frequencies of the different categories with distance from the canal discharge point were observed for salinity and conductivity. Temperature showed a fairly uniform distribution of percent frequencies while turbidity did not show any patterns.

The Kendall Rank-Correlation method was used to investigate possible trends in the data sets and to determine an optimal sampling frequency. Independence between sucessive observations is assumed to be established if the calculated probability of the rank score exceedance is greater than 0.05. Based on this criterion, the monthly observations were found to be independent with a mean probability of 0.48. The probability increased to 0.65 for sampling frequency of once in 2 months and did not change significantly with increasing frequency. Thus, the analyses did not indicate any trend or seasonality. This, however, may be because measurements were made just once, or in a few cases only several times in any one month.

The following recommendations are made:

It is recommended that future sampling be done at no more than two depths, preferably at 0.5 and 2.5 meters.

There is a need for the NPS to adopt threshold values that have physical meaning, for each measured variable, in the context of assesing man's action, such as canal discharges, on the bay environment.

The observed independence on the monthly observation level indicates that each such observation provides new information on the sampled variable. Therefore it is recommended that sampling be continued on a monthly bases particularly for those variables that were found to have high variability.

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APPENDIX 1.

SAMPLE STATISTICS FOR BENCHMARK SAMPLING STATIONS

STA$ = 4 DEPTH$ = 1

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	45	47	42	45	47	28	29	28	24
MINIMUM	0.920	2.100	0.630	2.230	0.570	4.440	0.000	0.000	0.000
MAXIMUM	34.000	51.000	4.200	8.570	7.630	42.780	4.470	90.500	9.600
MEAN	12.889	20.094	1.615	7.597	3.615	15.948	1.078	14.750	2.610
STANDARD DEV	10.673	15.816	0.871	0.885	1.788	10.091	1.195	22.384	2.613

STA$ = 4 DEPTH$ = 2

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	0	1	0	1	1	0	0	0	0
MINIMUM	.	33.400	.	7.860	4.200	.	.	.	.
MAXIMUM	.	33.400	.	7.860	4.200	.	.	.	.
MEAN	.	33.400	.	7.860	4.200	.	.	.	.
STANDARD DEV	.	0.000	.	0.000	0.000	.	.	.	.

STA$ = 4 DEPTH$ = 4

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	2	3	1	3	3	0	0	0	0
MINIMUM	14.570	25.300	3.300	7.600	1.000	.	.	.	.
MAXIMUM	21.990	57.600	3.300	8.810	2.690	.	.	.	.
MEAN	18.280	39.633	3.300	8.017	1.630	.	.	.	.
STANDARD DEV	5.247	16.454	0.000	0.687	0.923	.	.	.	.

STA$ = 4 DEPTH$ = 5

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	56	62	28	55	60	23	24	24	17
MINIMUM	2.930	4.890	0.700	7.140	0.090	0.000	0.020	0.160	0.000
MAXIMUM	36.330	54.700	6.800	8.640	8.600	72.140	4.150	18.480	8.650
MEAN	19.817	31.866	1.566	7.836	2.905	18.368	0.679	4.410	2.044
STANDARD DEV	7.961	11.511	1.341	0.395	1.966	18.479	0.946	5.012	2.388

Legend:
SALT = Salinity
TURB = Turbidity
DO = Dissolved Oxygen
NITRI= Nitrite Ion
PHOS = Phosphate Ion
COND = Conductivity
PH = pH
AMO = Ammonium Ion
NITRA= Nitrate Ion
TEMPW= Water Temperature
TEMPA= Air Temperature

STA$ = 11 DEPTH$ = 1

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	49	51	41	48	47	26	26	26	25
MINIMUM	5.000	7.200	0.300	0.150	0.330	0.290	0.000	0.000	0.010
MAXIMUM	38.050	57.900	4.100	9.020	8.850	32.340	1.610	134.010	1.000
MEAN	23.683	35.773	1.087	8.315	6.628	4.023	0.278	7.424	0.178
STANDARD DEV	8.050	12.958	0.919	1.242	1.460	6.992	0.411	26.121	0.262

STA$ = 11 DEPTH$ = 2

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	69	66	57	31	15	3	3	3	3
MINIMUM	5.200	8.700	0.240	7.000	4.240	1.380	0.000	0.000	0.000
MAXIMUM	38.800	57.810	4.900	8.950	8.980	31.820	0.150	5.580	0.370
MEAN	25.862	38.381	1.224	8.110	6.496	12.000	0.087	1.860	0.130
STANDARD DEV	7.095	10.118	0.997	0.513	1.453	17.179	0.078	3.222	0.208

STA$ = 11 DEPTH$ = 3

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	22	26	11	24	24	8	8	8	5
MINIMUM	10.310	7.300	0.490	7.930	5.370	0.000	0.000	0.010	0.000
MAXIMUM	38.000	58.700	7.500	9.080	9.800	6.200	0.140	5.820	0.100
MEAN	24.329	34.808	1.690	8.483	7.855	1.114	0.059	1.656	0.048
STANDARD DEV	7.050	11.368	2.022	0.325	1.190	2.155	0.047	2.384	0.042

STA$ = 11 DEPTH$ = 4

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	10	10	10	4	7	8	9	8	6
MINIMUM	18.040	33.850	0.300	7.930	5.700	0.000	0.030	0.000	0.000
MAXIMUM	28.980	48.000	1.900	8.490	9.800	4.760	0.510	13.110	0.160
MEAN	23.771	39.239	0.901	8.162	6.994	1.741	0.161	3.526	0.048
STANDARD DEV	3.703	5.587	0.497	0.245	1.384	1.553	0.149	4.744	0.061

STA$ = 11 DEPTH$ = 5

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	2	2	0	1	2	0	0	0	0
MINIMUM	22.140	36.200	.	7.700	2.800	.	.	.	.
MAXIMUM	26.370	41.610	.	7.700	5.500	.	.	.	.
MEAN	24.255	38.905	.	7.700	4.150	.	.	.	.
STANDARD DEV	2.991	3.825	.	0.000	1.909	.	.	.	.

STA$ = 15 DEPTH$ = 1

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	35	38	33	36	37	21	20	20	20
MINIMUM	19.500	32.500	0.320	7.990	4.500	0.000	0.000	0.000	0.000
MAXIMUM	40.000	60.300	3.050	8.750	8.780	2.020	0.150	5.860	0.090
MEAN	33.164	50.162	0.786	8.362	6.338	0.881	0.073	1.170	0.034
STANDARD DEV	4.369	6.018	0.474	0.145	1.019	0.572	0.055	1.598	0.029

STA$ = 15 DEPTH$ = 2

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	1	1	1	1	1	1	1	1	1
MINIMUM	32.000	51.900	0.610	8.250	6.400	3.710	0.090	1.000	0.290
MAXIMUM	32.000	51.900	0.610	8.250	6.400	3.710	0.090	1.000	0.290
MEAN	32.000	51.900	0.610	8.250	6.400	3.710	0.090	1.000	0.290
STANDARD DEV	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

STA$ = 15 DEPTH$ = 3

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	62	61	59	28	12	6	6	6	6
MINIMUM	20.560	31.200	0.260	7.000	4.770	0.400	0.040	0.720	0.010
MAXIMUM	40.000	60.800	2.350	8.610	8.620	18.270	0.240	5.210	0.360
MEAN	34.196	49.717	0.935	8.015	6.308	5.077	0.137	2.985	0.148
STANDARD DEV	3.270	6.462	0.501	0.398	1.091	6.851	0.070	1.691	0.128

STA$ = 15 DEPTH$ = 4

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	38	41	14	33	39	8	9	9	5
MINIMUM	20.350	33.700	0.350	7.880	4.610	0.000	0.000	0.000	0.000
MAXIMUM	39.620	59.800	2.200	8.740	8.700	2.900	0.320	1.770	0.520
MEAN	33.446	49.868	0.961	8.325	6.344	0.697	0.067	0.516	0.166
STANDARD DEV	4.271	6.318	0.595	0.181	0.946	1.075	0.102	0.554	0.217

STA$ = 15 DEPTH$ = 5

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	12	13	10	9	11	9	9	9	7
MINIMUM	29.370	38.000	0.320	7.990	5.040	0.000	0.000	0.000	0.000
MAXIMUM	39.620	59.900	1.100	8.360	8.660	1.830	0.380	3.620	0.040
MEAN	34.408	50.560	0.623	8.106	6.916	0.656	0.100	0.600	0.010
STANDARD DEV	3.359	6.266	0.260	0.140	1.129	0.706	0.115	1.153	0.015

STA$ = 18 DEPTH$ = 1

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	35	43	34	41	42	21	21	21	20
MINIMUM	29.520	46.100	0.000	8.010	5.000	0.000	0.000	0.000	0.000
MAXIMUM	38.950	59.600	3.700	8.770	8.760	1.490	0.120	0.920	0.070
MEAN	35.969	54.302	1.338	8.407	6.485	0.603	0.030	0.257	0.025
STANDARD DEV	1.801	2.548	0.750	0.160	0.898	0.459	0.036	0.247	0.025

STA$ = 18 DEPTH$ = 2

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	3	3	1	3	3	1	1	1	1
MINIMUM	20.490	33.900	0.640	8.390	5.310	1.380	0.000	0.000	0.000
MAXIMUM	36.410	54.800	0.640	8.400	6.040	1.380	0.000	0.000	0.000
MEAN	30.780	47.433	0.640	8.397	5.700	1.380	0.000	0.000	0.000
STANDARD DEV	8.925	11.736	0.000	0.006	0.368	0.000	0.000	0.000	0.000

STA$ = 18 DEPTH$ = 3

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	12	13	2	11	13	1	1	1	0
MINIMUM	29.440	46.000	1.440	8.010	4.800	0.630	0.020	0.110	.
MAXIMUM	38.000	59.600	2.200	8.780	8.250	0.630	0.020	0.110	.
MEAN	35.819	53.697	1.820	8.439	6.317	0.630	0.020	0.110	.
STANDARD DEV	2.453	3.710	0.537	0.215	1.002	0.000	0.000	0.000	.

STA$ = 18 DEPTH$ = 4

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	61	56	43	42	30	16	17	17	13
MINIMUM	20.350	33.700	0.230	7.000	4.790	0.000	0.000	0.000	0.000
MAXIMUM	38.370	60.200	6.000	8.710	8.900	2.100	0.060	1.350	0.310
MEAN	35.072	52.457	1.258	8.131	6.421	0.771	0.031	0.418	0.075
STANDARD DEV	2.398	5.189	0.960	0.394	0.985	0.669	0.020	0.403	0.104

STA$ = 18 DEPTH$ = 5

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	8	15	8	15	16	7	7	7	6
MINIMUM	31.780	46.850	0.630	7.880	5.700	0.000	0.000	0.000	0.000
MAXIMUM	39.620	59.330	3.900	8.600	8.410	1.750	0.170	0.670	3.540
MEAN	35.810	55.159	1.680	8.275	6.969	0.670	0.059	0.161	0.598
STANDARD DEV	2.320	3.194	1.070	0.194	0.641	0.727	0.056	0.243	1.441

STA$ = 19 DEPTH$ = 1

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	38	45	34	43	44	21	20	20	20
MINIMUM	31.070	48.100	0.350	7.960	0.190	0.000	0.000	0.000	0.000
MAXIMUM	38.290	57.800	2.100	8.700	9.110	4.290	0.170	0.380	0.090
MEAN	35.866	54.277	0.817	8.371	6.354	0.653	0.032	0.118	0.022
STANDARD DEV	1.367	2.057	0.385	0.146	1.475	0.933	0.046	0.128	0.027

STA$ = 19 DEPTH$ = 2

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	3	4	2	4	4	2	2	2	2
MINIMUM	19.570	32.600	0.480	8.210	4.510	0.550	0.050	0.210	0.000
MAXIMUM	42.000	54.400	0.580	8.370	8.710	0.890	0.170	0.450	0.120
MEAN	32.550	48.575	0.530	8.300	6.708	0.720	0.110	0.330	0.060
STANDARD DEV	11.624	10.665	0.071	0.067	1.945	0.240	0.085	0.170	0.085

STA$ = 19 DEPTH$ = 3

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	16	12	7	11	13	4	4	4	4
MINIMUM	32.960	50.500	0.320	8.000	5.350	0.010	0.040	0.000	0.010
MAXIMUM	42.000	58.440	1.350	9.290	8.160	0.920	0.770	0.930	0.330
MEAN	36.235	54.845	0.700	8.485	6.253	0.370	0.233	0.520	0.123
STANDARD DEV	1.855	2.269	0.361	0.361	0.886	0.432	0.359	0.442	0.145

STA$ = 19 DEPTH$ = 4

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	15	18	6	16	18	6	6	6	4
MINIMUM	32.010	43.810	0.450	7.960	4.280	0.000	0.000	0.000	0.000
MAXIMUM	39.200	58.200	2.100	8.530	8.760	0.540	0.040	0.150	0.250
MEAN	35.913	53.477	0.890	8.300	6.809	0.137	0.022	0.085	0.068
STANDARD DEV	1.785	3.583	0.618	0.155	1.148	0.203	0.016	0.067	0.122

STA$ = 19 DEPTH$ = 5

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	23	26	15	21	25	12	13	13	9
MINIMUM	20.350	33.700	0.400	3.420	4.800	0.000	0.000	0.000	0.000
MAXIMUM	37.000	60.000	2.600	8.600	8.900	6.900	0.190	0.390	0.060
MEAN	35.203	53.202	0.894	8.010	6.857	1.293	0.057	0.131	0.011
STANDARD DEV	3.370	5.279	0.539	1.065	1.133	2.021	0.050	0.138	0.021

STA = 29 DEPTH = 1

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	37	39	35	37	38	23	21	21	22
MINIMUM	30.840	47.800	0.360	0.380	5.030	0.000	0.000	0.000	0.00
MAXIMUM	38.710	57.600	2.200	8.670	8.780	1.130	0.210	0.600	0.27
MEAN	35.937	54.111	0.845	8.153	6.369	0.523	0.039	0.180	0.05
STANDARD DEV	1.441	2.071	0.445	1.321	0.889	0.387	0.064	0.168	0.07

STA = 29 DEPTH = 2

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	4	5	4	5	5	3	3	3	3
MINIMUM	34.000	53.800	0.500	8.160	7.070	0.020	0.020	0.140	0.09
MAXIMUM	38.000	58.500	0.830	8.680	8.600	0.570	0.170	0.560	0.30
MEAN	36.250	56.060	0.637	8.394	7.794	0.307	0.070	0.360	0.18
STANDARD DEV	1.708	2.152	0.157	0.196	0.547	0.276	0.087	0.211	0.11

STA = 29 DEPTH = 3

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	21	20	14	18	11	2	2	2	2
MINIMUM	20.070	33.300	0.340	7.460	4.700	0.820	0.050	0.000	0.00
MAXIMUM	37.300	58.600	1.200	8.510	7.130	1.630	0.050	0.330	0.00
MEAN	34.486	51.539	0.681	8.151	5.728	1.225	0.050	0.165	0.00
STANDARD DEV	3.580	6.378	0.258	0.309	0.737	0.573	0.000	0.233	0.00

STA = 29 DEPTH = 4

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	26	29	4	28	31	4	4	4	2
MINIMUM	20.560	34.000	0.580	7.880	4.760	0.000	0.000	0.000	0.00
MAXIMUM	37.720	56.400	3.400	8.670	8.590	9.990	0.080	1.340	0.01
MEAN	35.223	52.686	1.473	8.349	6.409	2.568	0.035	0.355	0.01
STANDARD DEV	3.389	4.559	1.298	0.182	0.955	4.949	0.041	0.657	0.01

STA = 29 DEPTH = 5

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	14	14	15	9	12	13	14	14	10
MINIMUM	34.050	47.540	0.410	7.950	5.500	0.000	0.000	0.000	0.00
MAXIMUM	40.120	60.250	1.000	8.200	8.900	2.000	0.170	0.300	0.26
MEAN	36.522	54.374	0.637	8.087	6.742	0.504	0.047	0.110	0.04
STANDARD DEV	1.527	4.536	0.197	0.083	1.049	0.610	0.044	0.100	0.08

STA$ = 35 DEPTH$ = 1

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	35	40	32	39	39	21	21	21	20
MINIMUM	4.070	1.900	0.370	0.370	0.190	0.000	0.000	0.000	0.000
MAXIMUM	39.000	58.900	2.000	8.710	8.480	1.860	0.440	5.260	0.160
MEAN	32.947	50.296	0.832	8.137	6.133	0.860	0.081	1.637	0.023
STANDARD DEV	6.329	9.302	0.422	1.285	1.335	0.568	0.103	1.434	0.038

STA$ = 35 DEPTH$ = 2

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	1	1	1	1	1	1	1	1	1
MINIMUM	33.000	51.700	0.500	8.280	6.730	3.490	0.180	1.600	0.130
MAXIMUM	33.000	51.700	0.500	8.280	6.730	3.490	0.180	1.600	0.130
MEAN	33.000	51.700	0.500	8.280	6.730	3.490	0.180	1.600	0.130
STANDARD DEV	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

STA$ = 35 DEPTH$ = 3

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	27	24	27	18	5	4	4	4	4
MINIMUM	19.850	33.000	0.220	7.120	4.900	1.080	0.090	0.380	0.000
MAXIMUM	39.000	59.300	1.450	8.590	8.930	6.200	0.200	2.830	0.400
MEAN	33.508	49.710	0.669	8.034	6.428	2.523	0.130	1.413	0.125
STANDARD DEV	3.603	6.681	0.275	0.320	1.841	2.460	0.050	1.043	0.188

STA$ = 35 DEPTH$ = 4

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	29	33	4	34	35	4	4	4	3
MINIMUM	30.530	41.920	1.060	8.020	4.840	0.170	0.000	0.340	0.020
MAXIMUM	38.950	57.900	3.200	8.710	7.600	1.670	0.260	3.970	0.200
MEAN	34.692	52.682	2.180	8.339	6.215	1.205	0.155	2.083	0.090
STANDARD DEV	2.525	3.663	0.992	0.128	0.718	0.698	0.120	1.588	0.096

STA$ = 35 DEPTH$ = 5

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	18	21	18	17	22	15	16	16	11
MINIMUM	20.920	34.500	0.330	7.980	0.550	0.000	0.000	0.210	0.000
MAXIMUM	39.040	58.770	1.200	8.520	8.930	2.900	0.230	3.670	0.290
MEAN	32.959	48.154	0.734	8.177	6.395	0.861	0.077	0.806	0.035
STANDARD DEV	5.077	7.223	0.301	0.161	1.755	1.039	0.065	0.835	0.086

STA$ = 39 DEPTH$ = 1

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	35	38	34	37	37	22	22	21	21
MINIMUM	33.200	48.000	0.370	7.910	5.010	0.000	0.000	0.000	0.000
MAXIMUM	39.700	58.800	1.990	8.790	8.770	1.830	0.420	1.600	0.090
MEAN	36.413	54.412	0.764	8.394	6.264	0.754	0.070	0.344	0.020
STANDARD DEV	1.515	2.379	0.322	0.161	0.843	0.626	0.113	0.389	0.026

STA$ = 39 DEPTH$ = 2

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	3	3	3	3	3	2	2	2	2
MINIMUM	37.000	57.800	0.480	0.610	7.050	0.020	0.020	0.270	0.110
MAXIMUM	38.000	60.200	0.530	8.760	8.040	0.510	0.050	0.610	0.350
MEAN	37.667	58.833	0.503	5.897	7.443	0.265	0.035	0.440	0.230
STANDARD DEV	0.577	1.234	0.025	4.584	0.525	0.346	0.021	0.240	0.170

STA$ = 39 DEPTH$ = 3

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	14	14	12	11	5	2	2	2	2
MINIMUM	20.850	34.400	0.350	6.750	5.200	1.140	0.040	0.480	0.020
MAXIMUM	37.330	58.540	1.250	8.400	8.130	1.850	0.340	0.580	0.120
MEAN	33.581	50.555	0.709	7.977	6.226	1.495	0.190	0.530	0.070
STANDARD DEV	3.875	7.228	0.285	0.461	1.201	0.502	0.212	0.071	0.071

STA$ = 39 DEPTH$ = 4

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	24	24	4	24	25	4	4	4	3
MINIMUM	33.200	44.440	0.640	7.910	5.070	0.440	0.000	0.280	0.000
MAXIMUM	38.290	57.100	3.700	8.710	7.860	2.200	0.190	1.400	0.170
MEAN	36.346	54.339	2.005	8.372	6.063	1.397	0.065	0.592	0.080
STANDARD DEV	1.309	2.636	1.487	0.168	0.738	0.818	0.086	0.539	0.085

STA$ = 39 DEPTH$ = 5

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	26	29	18	23	28	16	17	16	12
MINIMUM	21.060	34.700	0.440	8.050	4.810	0.000	0.000	0.000	0.000
MAXIMUM	40.370	59.750	2.600	8.800	8.760	27.300	0.190	1.410	0.050
MEAN	35.860	53.202	0.818	8.310	6.700	2.234	0.045	0.289	0.013
STANDARD DEV	3.434	5.240	0.531	0.207	0.944	6.719	0.048	0.353	0.019

STA$ = 78 DEPTH$ = 1

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	35	38	33	37	37	22	22	22	21
MINIMUM	26.780	42.500	0.560	7.970	4.790	0.000	0.000	0.000	0.000
MAXIMUM	39.040	58.000	2.500	8.710	8.720	1.860	0.150	1.650	0.070
MEAN	35.576	53.494	1.005	8.372	6.337	0.857	0.033	0.417	0.020
STANDARD DEV	2.585	3.487	0.513	0.161	0.887	0.588	0.044	0.376	0.026

STA$ = 78 DEPTH$ = 2

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	1	1	1	1	1	1	1	1	1
MINIMUM	34.000	53.900	0.850	8.320	7.070	2.230	0.050	1.140	0.070
MAXIMUM	34.000	53.900	0.850	8.320	7.070	2.230	0.050	1.140	0.070
MEAN	34.000	53.900	0.850	8.320	7.070	2.230	0.050	1.140	0.070
STANDARD DEV	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

STA$ = 78 DEPTH$ = 3

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	3	4	3	3	3	3	3	3	3
MINIMUM	34.000	51.600	0.610	0.080	6.700	0.000	0.020	0.330	0.000
MAXIMUM	40.540	59.800	0.930	8.370	8.160	1.610	0.060	1.890	0.160
MEAN	37.513	55.500	0.810	5.583	7.263	0.650	0.043	1.110	0.057
STANDARD DEV	3.297	4.303	0.174	4.766	0.785	0.849	0.021	0.780	0.090

STA$ = 78 DEPTH$ = 4

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	44	44	37	32	18	5	5	5	3
MINIMUM	19.780	32.900	0.200	7.000	4.940	0.000	0.000	0.000	0.000
MAXIMUM	38.400	58.750	3.800	8.550	8.000	2.060	0.060	0.850	0.020
MEAN	34.881	51.821	1.016	8.070	6.344	0.964	0.028	0.414	0.010
STANDARD DEV	2.747	5.312	0.840	0.365	0.935	0.790	0.028	0.326	0.010

STA$ = 78 DEPTH$ = 5

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	34	37	13	34	38	12	13	14	10
MINIMUM	20.920	34.500	0.590	7.970	4.660	0.000	0.000	0.000	0.000
MAXIMUM	39.120	59.800	2.300	8.740	8.740	2.310	0.140	1.590	0.360
MEAN	35.270	52.931	0.949	8.318	6.449	0.967	0.058	0.482	0.051
STANDARD DEV	3.604	5.231	0.471	0.188	0.904	0.835	0.041	0.440	0.111

STA$ = 92 DEPTH$ = 1

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	85	85	81	56	40	22	22	22	21
MINIMUM	18.450	31.000	0.250	6.880	2.790	0.000	0.000	0.000	0.000
MAXIMUM	39.600	58.600	4.600	8.890	8.720	2.970	0.320	9.470	0.090
MEAN	33.067	49.193	0.631	8.190	5.700	1.001	0.063	1.414	0.021
STANDARD DEV	4.147	6.553	0.527	0.362	1.360	0.752	0.081	2.180	0.026

STA$ = 92 DEPTH$ = 2

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	14	15	0	16	16	0	0	0	0
MINIMUM	26.630	42.300	.	7.910	3.620	.	.	.	.
MAXIMUM	39.450	58.500	.	8.920	8.580	.	.	.	.
MEAN	35.466	52.913	.	8.356	5.853	.	.	.	.
STANDARD DEV	3.362	4.840	.	0.221	1.286	.	.	.	.

STA$ = 92 DEPTH$ = 3

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	16	17	4	14	15	3	3	3	2
MINIMUM	18.380	30.900	0.280	8.010	1.400	0.000	0.020	0.280	0.000
MAXIMUM	38.870	57.800	1.400	8.570	8.330	0.900	0.090	1.900	0.020
MEAN	30.088	45.314	0.642	8.326	5.526	0.300	0.053	0.873	0.010
STANDARD DEV	6.398	9.035	0.511	0.179	1.951	0.520	0.035	0.893	0.014

STA$ = 92 DEPTH$ = 4

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	11	11	16	10	14	14	15	15	10
MINIMUM	20.900	41.440	0.310	8.000	4.400	0.000	0.000	0.030	0.000
MAXIMUM	38.710	57.600	1.400	8.200	9.000	6.450	0.180	1.660	1.690
MEAN	31.835	47.164	0.614	8.098	6.606	1.134	0.059	0.623	0.204
STANDARD DEV	4.771	5.635	0.270	0.076	1.352	1.819	0.053	0.477	0.529

STA$ = 92 DEPTH$ = 5

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	1	1	0	0	1	0	0	0	0
MINIMUM	35.040	53.360	.	.	7.100	.	.	.	.
MAXIMUM	35.040	53.360	.	.	7.100	.	.	.	.
MEAN	35.040	53.360	.	.	7.100	.	.	.	.
STANDARD DEV	0.000	0.000	.	.	0.000	.	.	.	.

STA$ = 96 DEPTH$ = 1

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	37	39	36	37	37	22	21	21	21
MINIMUM	23.300	30.100	0.330	7.910	4.590	0.000	0.000	0.190	0.000
MAXIMUM	58.000	58.100	1.600	8.660	8.660	7.190	0.150	2.380	0.120
MEAN	35.090	51.383	0.746	8.321	6.115	1.030	0.057	0.801	0.032
STANDARD DEV	5.015	5.615	0.328	0.148	1.040	1.455	0.051	0.534	0.032

STA$ = 96 DEPTH$ = 2

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	9	9	6	9	9	6	6	6	6
MINIMUM	19.570	32.600	0.430	8.190	4.350	0.280	0.020	0.480	0.000
MAXIMUM	38.050	56.800	0.710	8.470	7.800	3.130	0.100	1.670	0.210
MEAN	32.408	49.978	0.583	8.282	5.852	1.602	0.057	0.995	0.082
STANDARD DEV	5.501	7.398	0.101	0.086	1.185	1.277	0.029	0.459	0.097

STA$ = 96 DEPTH$ = 3

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	61	60	44	35	19	0	0	0	0
MINIMUM	30.930	37.400	0.260	7.100	4.330	.	.	.	.
MAXIMUM	58.500	58.940	1.500	8.650	8.890	.	.	.	.
MEAN	35.066	51.244	0.717	8.104	5.695	.	.	.	.
STANDARD DEV	3.598	5.066	0.325	0.351	0.997	.	.	.	.

STA$ = 96 DEPTH$ = 4

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	25	27	16	24	28	14	15	15	11
MINIMUM	20.560	34.000	0.430	8.000	3.980	0.000	0.010	0.180	0.000
MAXIMUM	38.790	59.950	5.400	8.640	9.000	9.140	0.140	1.120	0.370
MEAN	33.297	49.295	1.203	8.239	6.602	1.427	0.057	0.609	0.044
STANDARD DEV	4.349	6.804	1.288	0.159	1.113	2.477	0.036	0.275	0.109

STA$ = 96 DEPTH$ = 5

	SALT	COND	TURB	PH	DO	AMO	NITRI	NITRA	PHOS
N OF CASES	3	4	3	3	5	3	3	3	1
MINIMUM	34.290	45.900	0.570	7.990	4.800	0.710	0.000	0.350	0.000
MAXIMUM	36.200	58.250	1.100	8.190	8.260	1.600	0.130	1.850	0.000
MEAN	35.303	52.878	0.803	8.110	6.552	1.153	0.083	0.883	0.000
STANDARD DEV	0.960	5.351	0.271	0.106	1.272	0.445	0.072	0.839	0.000

APPENDIX 2.

SAMPLE STATISTICS BY YEAR, SEASON AND REGION

APPENDIX 3. Sample Statistics by Year, Season and Region

YEAR = 79 SEASON = 1 REGION = 1

TOTAL OBSERVATIONS: 9

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	9	9	9	9	9	9
MINIMUM	19.410	27.150	18.400	0.740	7.600	3.100
MAXIMUM	35.500	49.620	23.300	3.200	8.300	9.600
MEAN	27.733	37.941	20.199	1.556	8.018	5.711
STANDARD DEV	5.563	7.661	1.554	0.848	0.249	2.180

YEAR = 79 SEASON = 1 REGION = 2

TOTAL OBSERVATION: 66

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	66	66	66	66	66	66
MINIMUM	29.840	34.350	16.200	0.320	8.000	6.400
MAXIMUM	39.890	52.850	22.150	3.900	8.210	8.900
MEAN	35.292	47.205	19.170	0.955	8.112	7.352
STANDARD DEV	1.879	3.738	1.722	0.502	0.054	0.545

YEAR = 79 SEASON = 1 REGION = 3

TOTAL OBSERVATIONS: 18

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	18	17	18	18	18	18
MINIMUM	22.810	31.050	17.200	0.440	7.320	1.200
MAXIMUM	36.680	51.870	24.120	3.500	8.500	9.800
MEAN	30.603	42.285	19.941	1.051	8.072	6.628
STANDARD DEV	3.917	6.099	1.984	0.723	0.392	2.927

YEAR = 79 SEASON = 2 REGION = 1

TOTAL OBSERVATIONS: 9

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	6	6	9	9	3	3
MINIMUM	0.920	2.100	26.400	0.540	8.200	2.780
MAXIMUM	33.910	51.700	28.900	2.100	8.200	6.160
MEAN	19.910	32.033	27.771	1.157	8.200	3.997
STANDARD DEV	11.741	17.719	0.704	0.526	0.000	1.878

YEAR = 79 SEASON = 2 REGION = 2

TOTAL OBSERVATIONS: 66

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	58	58	66	66	31	12
MINIMUM	36.840	56.700	0.960	0.330	8.000	4.160
MAXIMUM	40.700	60.180	29.100	1.400	8.500	5.130
MEAN	38.963	58.420	27.189	0.598	8.168	4.849
STANDARD DEV	0.856	0.940	3.401	0.181	0.133	0.314

YEAR = 79 SEASON = 3 REGION = 2

TOTAL OBSERVATIONS: 18

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	13	13	18	18	9	9
MINIMUM	21.420	35.200	25.590	0.390	7.800	0.320
MAXIMUM	39.780	58.900	29.800	3.700	8.500	6.160
MEAN	33.418	50.992	27.636	1.141	8.089	4.136
STANDARD DEV	5.885	7.616	0.919	0.985	0.257	2.206

YEAR = 79 SEASON = 3 REGION = 1

TOTAL OBSERVATIONS: 18

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	15	15	18	9	9	17
MINIMUM	0.970	2.200	28.000	0.640	7.600	0.270
MAXIMUM	27.840	43.900	32.600	1.600	8.620	5.520
MEAN	12.129	20.900	30.100	1.001	8.069	3.331
STANDARD DEV	7.708	12.157	1.478	0.344	0.313	1.534

YEAR = 79 SEASON = 3 REGION = 2

TOTAL OBSERVATIONS: 88

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	66	66	88	66	66	88
MINIMUM	19.430	32.400	28.000	0.230	8.200	3.090
MAXIMUM	39.700	58.800	32.500	1.900	8.630	7.760
MEAN	26.410	41.608	29.841	0.622	8.443	5.743
STANDARD DEV	8.529	11.117	1.468	0.296	0.115	0.999

YEAR = 79 SEASON = 3 REGION = 3

TOTAL OBSERVATIONS: 26

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	19	19	26	18	18	24
MINIMUM	15.040	26.000	27.700	0.250	7.700	1.680
MAXIMUM	36.000	54.300	32.600	2.700	8.860	8.960
MEAN	21.985	35.795	29.923	0.856	8.299	5.073
STANDARD DEV	6.075	8.139	1.585	0.695	0.405	2.205

YEAR = 79 SEASON = 4 REGION = 1

TOTAL OBSERVATIONS: 18

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	15	15	18	6	18	18
MINIMUM	0.190	0.600	23.500	0.610	7.310	0.300
MAXIMUM	23.520	38.100	27.500	1.400	8.340	5.500
MEAN	8.601	15.147	25.317	0.822	7.664	3.409
STANDARD DEV	7.773	12.456	1.160	0.295	0.271	1.535

YEAR = 79 SEASON = 4 REGION = 2

TOTAL OBSERVATIONS: 133

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	111	111	133	44	133	133
MINIMUM	19.430	32.400	22.800	0.000	8.180	5.300
MAXIMUM	37.470	56.100	27.500	5.100	8.560	7.550
MEAN	33.099	50.608	24.932	1.410	8.331	6.387
STANDARD DEV	4.500	5.836	1.645	1.123	0.079	0.461

YEAR = 79 SEASON = 4 REGION = 3

TOTAL OBSERVATIONS: 35

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	29	29	35	12	35	34
MINIMUM	6.490	12.400	22.700	0.360	6.690	0.120
MAXIMUM	30.140	46.900	27.600	3.250	8.700	9.480
MEAN	21.013	34.390	25.197	1.028	8.008	5.425
STANDARD DEV	5.784	8.259	1.533	0.892	0.587	2.703

YEAR = 80 SEASON = 1 REGION = 1

TOTAL OBSERVATIONS: 18

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	18	18	18	9	18	18
MINIMUM	1.170	2.600	19.000	0.540	7.440	1.200
MAXIMUM	29.060	45.500	27.300	2.000	8.590	6.880
MEAN	17.260	29.067	22.722	1.124	7.987	4.659
STANDARD DEV	7.804	11.656	2.516	0.479	0.350	1.781

YEAR = 80 SEASON = 1 REGION = 2

TOTAL OBSERVATIONS: 132

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	132	132	132	65	132	132
MINIMUM	29.520	46.100	17.500	0.380	0.380	5.580
MAXIMUM	37.220	55.800	25.600	2.200	8.510	7.510
MEAN	35.136	53.223	21.598	0.801	8.308	6.688
STANDARD DEV	1.665	2.085	2.935	0.307	0.698	0.459

YEAR = 80 SEASON = 1 REGION = 3

TOTAL OBSERVATIONS: 36

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	36	36	36	19	36	35
MINIMUM	21.990	36.000	17.300	0.000	7.060	0.450
MAXIMUM	33.040	50.600	25.900	1.500	8.950	9.920
MEAN	27.519	43.447	22.028	0.668	8.186	5.875
STANDARD DEV	2.457	3.242	2.776	0.357	0.541	2.632

YEAR = 80 SEASON = 2 REGION = 1

TOTAL OBSERVATIONS: 18

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	18	18	18	9	18	18
MINIMUM	0.920	2.100	25.700	0.470	7.300	0.230
MAXIMUM	37.220	55.800	29.900	4.100	8.740	9.080
MEAN	16.783	27.306	27.706	1.769	8.066	4.643
STANDARD DEV	12.133	18.028	1.433	1.132	0.439	2.082

YEAR = 80 SEASON = 2 REGION = 2

TOTAL OBSERVATIONS: 132

	SALT	CONE	TEMP	TURB	PH	DO
N OF CASES	132	132	132	65	132	132
MINIMUM	27.380	43.300	25.900	0.260	8.180	3.780
MAXIMUM	39.450	58.500	30.000	1.300	8.830	7.380
MEAN	37.430	56.035	27.743	0.646	8.490	5.808
STANDARD DEV	1.891	2.354	1.327	0.191	0.178	0.605

YEAR = 80 SEASON = 2 REGION = 3

TOTAL OBSERVATIONS: 36

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	36	36	36	17	36	36
MINIMUM	15.240	26.300	25.800	0.310	6.940	0.910
MAXIMUM	39.040	58.000	30.800	8.800	8.810	6.810
MEAN	31.512	48.400	28.033	1.462	8.197	4.724
STANDARD DEV	7.064	9.276	1.698	2.085	0.476	1.654

YEAR = 80 SEASON = 3 REGION = 1

TOTAL OBSERVATIONS: 18

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	18	18	18	9	18	18
MINIMUM	0.000	0.100	27.200	0.570	7.140	0.090
MAXIMUM	35.110	53.200	31.600	1.800	8.380	6.510
MEAN	12.761	21.150	28.867	1.118	7.696	3.337
STANDARD DEV	11.600	17.737	1.242	0.421	0.316	1.977

YEAR = 80 SEASON = 3 REGION = 2

TOTAL OBSERVATIONS: 132

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	132	132	132	66	132	132
MINIMUM	2.550	5.300	28.500	0.430	8.150	3.060
MAXIMUM	39.290	58.300	31.600	1.600	8.550	7.350
MEAN	35.932	54.139	29.845	0.817	8.353	5.280
STANDARD DEV	3.587	4.999	0.929	0.310	0.089	0.771

YEAR = 80 SEASON = 3 REGION = 3

TOTAL OBSERVATIONS: 36

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	36	36	36	18	36	36
MINIMUM	10.060	18.300	27.100	0.380	6.960	0.110
MAXIMUM	38.130	56.900	31.800	4.900	8.630	8.290
MEAN	27.494	43.092	29.564	1.476	8.058	4.233
STANDARD DEV	7.857	10.544	1.216	1.386	0.511	2.040

YEAR = 80 SEASON = 4 REGION = 1

TOTAL OBSERVATIONS: 18

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	18	18	18	9	18	18
MINIMUM	0.240	0.700	21.900	0.600	7.230	1.510
MAXIMUM	26.560	42.200	25.900	4.200	8.490	6.680
MEAN	10.553	18.096	23.883	1.422	7.811	4.678
STANDARD DEV	8.910	14.282	1.375	1.124	0.296	1.246

YEAR = 80 SEASON = 4 REGION = 2

TOTAL OBSERVATIONS: 131

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	131	131	131	66	131	131
MINIMUM	17.830	30.100	20.400	0.270	8.150	5.750
MAXIMUM	35.440	53.600	25.900	3.200	8.720	7.950
MEAN	30.917	47.837	23.066	1.018	8.385	6.638
STANDARD DEV	3.481	4.548	1.712	0.721	0.143	0.476

YEAR = 80 SEASON = 4 REGION = 3

TOTAL OBSERVATIONS: 36

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	36	36	36	18	36	36
MINIMUM	6.310	12.100	19.900	0.400	6.900	1.020
MAXIMUM	28.680	45.000	26.500	6.300	8.780	8.790
MEAN	21.766	35.503	23.408	1.693	7.994	6.068
STANDARD DEV	4.998	7.176	1.774	1.700	0.556	2.093

YEAR = 81 SEASON = 1 REGION = 1

TOTAL OBSERVATIONS: 12

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	12	12	12	6	12	12
MINIMUM	3.720	7.500	12.600	0.570	7.550	2.530
MAXIMUM	29.600	46.200	23.300	2.300	8.600	7.750
MEAN	19.833	32.342	18.525	1.252	8.164	5.574
STANDARD DEV	8.860	13.300	4.716	0.618	0.328	1.790

YEAR = 81 SEASON = 1 REGION = 2

TOTAL OBSERVATIONS: 88

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	88	88	88	46	88	88
MINIMUM	26.260	25.600	11.500	0.570	8.130	5.170
MAXIMUM	36.000	54.300	22.700	3.700	8.700	8.500
MEAN	33.348	50.737	17.501	1.423	8.438	6.605
STANDARD DEV	2.341	3.976	4.942	0.556	0.100	0.684

YEAR = 81 SEASON = 1 REGION = 3

TOTAL OBSERVATIONS: 24

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	24	24	24	12	24	24
MINIMUM	19.930	33.100	11.600	0.430	7.380	3.210
MAXIMUM	32.250	49.600	23.500	1.500	8.910	8.870
MEAN	26.532	42.079	18.021	0.930	8.313	6.359
STANDARD DEV	3.169	4.215	5.134	0.321	0.426	1.576

YEAR = 81 SEASON = 2 REGION = 1

TOTAL OBSERVATIONS: 18

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	18	18	18	9	18	18
MINIMUM	0.580	1.400	24.700	0.620	7.840	1.430
MAXIMUM	37.390	56.000	32.000	2.600	8.750	7.550
MEAN	27.759	42.911	28.661	1.249	8.376	3.905
STANDARD DEV	11.199	16.321	2.796	0.636	0.225	1.907

YEAR = 81 SEASON = 2 REGION = 2

TOTAL OBSERVATIONS: 133

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	133	133	133	66	133	133
MINIMUM	27.760	43.800	23.700	0.330	8.210	3.580
MAXIMUM	38.540	57.400	31.300	2.300	8.780	7.590
MEAN	36.972	55.483	27.832	0.666	8.413	5.726
STANDARD DEV	1.197	1.490	2.548	0.292	0.109	0.691

YEAR = 81 SEASON = 2 REGION = 3

TOTAL OBSERVATIONS: 35

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	35	35	35	18	35	35
MINIMUM	26.180	41.700	24.800	0.420	7.290	0.900
MAXIMUM	37.960	56.700	31.100	3.000	8.770	8.980
MEAN	35.055	53.077	28.597	0.948	8.356	5.311
STANDARD DEV	3.256	4.106	2.285	0.645	0.405	1.751

YEAR = 81 SEASON = 3 REGION = 1

TOTAL OBSERVATIONS: 18

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	18	18	18	9	18	18
MINIMUM	0.290	0.800	26.400	0.610	7.220	1.020
MAXIMUM	39.290	58.300	31.700	2.900	8.820	7.660
MEAN	23.694	36.467	29.872	1.097	8.017	4.307
STANDARD DEV	15.751	23.069	1.819	0.714	0.474	1.746

YEAR = 81 SEASON = 3 REGION = 2

TOTAL OBSERVATIONS: 132

	SALT	COND	TEMP	TURB	PH	DO	
N OF CASES	131	131	132	66	131	130	
MINIMUM	2.810	5.800	0.000	0.320	7.870	2.790	
MAXIMUM	39.950	59.100	31.300	1.600	8.550	5.950	
MEAN	35.662	53.763	29.814	0.588	8.169	4.954	
STANDARD DEV		4.579	6.129	2.646	0.254	0.165	0.456

YEAR = 81 SEASON = 3 REGION = 3

TOTAL OBSERVATIONS: 36

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	36	36	36	16	36	36
MINIMUM	15.040	26.000	26.200	0.320	6.730	0.380
MAXIMUM	40.620	59.900	31.200	1.650	8.750	7.530
MEAN	32.835	49.978	29.756	0.743	8.015	4.294
STANDARD DEV	8.417	10.983	1.097	0.395	0.511	1.519

YEAR = 81 SEASON = 4 REGION = 1

TOTAL OBSERVATIONS: 12

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	12	12	12	6	12	12
MINIMUM	0.820	1.900	22.900	0.460	7.460	1.930
MAXIMUM	24.100	38.900	27.200	3.100	8.240	6.030
MEAN	8.792	15.417	24.700	1.672	7.720	4.383
STANDARD DEV	8.198	13.018	1.637	1.115	0.233	1.095

YEAR = 81 SEASON = 4 REGION = 2

TOTAL OBSERVATIONS: 88

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	88	88	88	44	88	88
MINIMUM	14.110	24.600	20.500	0.440	0.020	5.500
MAXIMUM	34.550	52.500	26.100	2.800	8.630	8.420
MEAN	26.591	42.105	23.323	1.369	8.124	6.648
STANDARD DEV	4.929	6.652	2.123	0.664	0.901	0.661

YEAR = 81 SEASON = 4 REGION = 3

TOTAL OBSERVATIONS: 24

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	24	24	24	13	24	24
MINIMUM	8.390	5.600	2.000	0.300	0.100	0.080
MAXIMUM	23.740	38.400	26.800	4.100	8.340	8.460
MEAN	16.836	26.742	21.304	1.421	6.960	5.232
STANDARD DEV	5.519	10.574	6.925	0.919	2.656	2.491

YEAR = 82 SEASON = 1 REGION = 1

TOTAL OBSERVATIONS: 16

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	16	16	16	8	16	16
MINIMUM	18.520	31.100	20.600	0.600	7.450	1.280
MAXIMUM	36.650	55.100	28.600	3.300	8.790	6.240
MEAN	27.979	43.944	25.468	1.594	8.232	4.095
STANDARD DEV	5.157	6.802	2.854	1.051	0.399	1.613

YEAR = 82 SEASON = 1 REGION = 2

TOTAL OBSERVATIONS: 132

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	132	132	132	66	125	132
MINIMUM	30.600	47.500	18.800	0.330	8.020	4.780
MAXIMUM	37.720	56.400	28.000	1.750	8.550	6.580
MEAN	35.253	53.357	24.061	0.707	8.376	5.699
STANDARD DEV	1.853	2.312	3.415	0.287	0.097	0.339

YEAR = 82 SEASON = 1 REGION = 3

TOTAL OBSERVATIONS: 36

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	36	36	36	18	36	36
MINIMUM	21.780	35.700	19.400	0.500	7.230	0.450
MAXIMUM	37.140	55.700	28.300	4.000	8.840	6.850
MEAN	31.387	48.417	24.497	1.572	8.270	4.727
STANDARD DEV	4.134	5.335	2.949	0.913	0.455	1.762

YEAR = 82 SEASON = 2 REGION = 1

TOTAL OBSERVATIONS: 18

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	18	18	18	9	18	18
MINIMUM	0.340	0.900	25.300	0.450	7.390	2.480
MAXIMUM	32.960	50.500	31.000	2.300	8.590	7.630
MEAN	11.820	19.928	27.017	1.397	7.927	4.497
STANDARD DEV	10.314	15.947	1.811	0.648	0.414	1.473

YEAR = 82 SEASON = 2 REGION = 2

TOTAL OBSERVATIONS: 134

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	134	134	134	63	134	134
MINIMUM	4.070	1.900	5.700	0.490	0.370	0.190
MAXIMUM	38.370	57.200	40.600	2.100	9.290	8.160
MEAN	35.067	53.013	27.033	0.939	8.385	5.857
STANDARD DEV	3.592	5.385	3.238	0.387	0.856	1.015

YEAR = 82 SEASON = 2 REGION = 3

TOTAL OBSERVATIONS: 34

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	34	34	34	17	34	34
MINIMUM	14.440	25.100	23.900	0.570	7.150	0.230
MAXIMUM	34.550	52.500	31.600	5.800	9.290	8.850
MEAN	26.511	41.947	27.456	1.768	8.306	5.426
STANDARD DEV	5.791	7.817	2.461	1.662	0.630	2.519

YEAR = 83 SEASON = 1 REGION = 1

TOTAL OBSERVATIONS: 12

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	0	12	12	0	12	12
MINIMUM	.	1.000	19.100	.	7.190	2.650
MAXIMUM	.	35.400	23.800	.	8.150	8.720
MEAN	.	10.252	21.717	.	7.548	5.238
STANDARD DEV	.	11.616	1.566	.	0.303	2.087

YEAR = 83 SEASON = 1 REGION = 2

TOTAL OBSERVATIONS: 88

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	0	88	88	0	88	86
MINIMUM	.	33.600	17.200	.	8.050	8.000
MAXIMUM	.	52.700	20.900	.	8.420	8.940
MEAN	.	45.368	19.028	.	8.281	8.547
STANDARD DEV	.	5.133	1.160	.	0.089	0.206

YEAR = 83 SEASON = 1 REGION = 3

TOTAL OBSERVATIONS: 26

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	0	26	26	0	26	26
MINIMUM	.	7.200	17.200	.	6.670	0.210
MAXIMUM	.	44.300	24.800	.	8.630	9.220
MEAN	.	29.204	20.245	.	7.835	6.015
STANDARD DEV	.	10.442	2.247	.	0.594	3.106

YEAR = 83 SEASON = 2 REGION = 1

TOTAL OBSERVATIONS: 14

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	11	14	14	12	14	14
MINIMUM	2.000	1.700	26.900	0.910	7.410	0.730
MAXIMUM	34.000	54.500	30.600	3.900	8.890	8.160
MEAN	17.273	33.921	29.150	1.812	8.199	4.953
STANDARD DEV	10.316	16.248	0.997	0.906	0.549	2.172

YEAR = 83 SEASON = 2 REGION = 2

TOTAL OBSERVATIONS: 75

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	41	58	58	42	59	59
MINIMUM	30.000	47.000	27.500	0.000	0.000	0.000
MAXIMUM	40.000	58.300	30.000	7.500	8.660	9.110
MEAN	36.024	55.253	29.153	0.921	8.151	7.110
STANDARD DEV	2.593	2.575	0.483	1.086	1.487	1.226

YEAR = 83 SEASON = 2 REGION = 3

TOTAL OBSERVATIONS: 17

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	13	15	15	13	15	15
MINIMUM	20.000	32.900	27.600	0.440	7.020	0.220
MAXIMUM	37.000	55.700	30.400	7.000	8.770	9.170
MEAN	29.154	46.513	29.067	1.758	8.148	5.727
STANDARD DEV	6.362	8.123	0.793	2.173	0.548	2.855

YEAR = 83 SEASON = 3 REGION = 1

TOTAL OBSERVATIONS: 18

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	17	18	18	18	18	18
MINIMUM	2.000	2.500	27.600	0.550	7.370	0.570
MAXIMUM	29.000	47.400	33.600	2.100	8.310	7.080
MEAN	14.941	24.561	30.783	1.104	7.757	4.003
STANDARD DEV	8.941	15.128	1.798	0.335	0.347	1.958

YEAR = 83 SEASON = 3 REGION = 2

TOTAL OBSERVATIONS: 91

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	63	77	77	63	77	77
MINIMUM	27.000	43.300	30.200	0.370	8.210	5.470
MAXIMUM	38.000	58.800	32.800	1.600	8.460	8.400
MEAN	34.238	54.243	31.468	0.692	8.313	6.711
STANDARD DEV	2.263	3.316	0.678	0.274	0.054	0.630

YEAR = 83 SEASON = 3 REGION = 3

TOTAL OBSERVATIONS: 18

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	18	18	18	18	18	18
MINIMUM	6.000	10.300	29.300	0.450	7.030	0.580
MAXIMUM	38.000	52.000	33.200	4.300	8.460	7.570
MEAN	24.139	37.700	31.033	1.212	7.940	5.343
STANDARD DEV	7.821	11.713	1.163	0.942	0.503	2.073

YEAR = 83 SEASON = 4 REGION = 1

TOTAL OBSERVATIONS: 18

	SALT	COND	TEMP	TURB	PH	DO	
N OF CASES	10	18	18	6	18	18	
MINIMUM	2.000	2.100	20.800	0.990	2.230	4.200	
MAXIMUM	22.000	41.900	29.200	2.600	8.350	8.600	
MEAN	9.600	21.600	24.506	1.530	7.503	6.053	
STANDARD DEV	6.535	14.042	2.864	0.590	1.360		1.282

YEAR = 83 SEASON = 4 REGION = 2

TOTAL OBSERVATIONS: 61

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	22	59	59	22	59	59
MINIMUM	30.000	39.400	19.900	0.520	0.080	5.100
MAXIMUM	42.000	55.300	29.700	6.500	8.400	8.940
MEAN	33.955	50.615	24.615	1.615	8.128	7.579
STANDARD DEV	2.591	3.157	3.553	1.431	1.069	0.833

YEAR = 83 SEASON = 4 REGION = 3

TOTAL OBSERVATIONS: 17

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	7	17	17	6	17	17
MINIMUM	5.000	11.300	19.800	0.400	7.260	1.990
MAXIMUM	28.000	49.700	30.100	8.700	8.470	8.680
MEAN	21.857	37.082	24.847	2.900	8.019	6.507
STANDARD DEV	7.819	8.231	3.906	3.559	0.417	2.267

YEAR = 84 SEASON = 1 REGION = 1

TOTAL OBSERVATIONS: 6

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	3	6	6	6	6	6
MINIMUM	3.000	5.500	24.100	0.880	7.540	5.100
MAXIMUM	23.000	45.900	25.500	9.400	8.410	8.260
MEAN	15.000	28.950	24.983	2.528	8.170	6.848
STANDARD DEV	10.583	14.500	0.605	3.375	0.334	1.389

YEAR = 84 SEASON = 1 REGION = 2

TOTAL OBSERVATIONS: 32

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	19	32	31	31	32	32
MINIMUM	31.000	47.700	22.900	0.370	8.180	0.550
MAXIMUM	37.000	57.400	25.400	2.200	8.440	9.340
MEAN	35.158	54.631	23.626	0.797	8.357	7.973
STANDARD DEV	1.675	2.094	0.610	0.426	0.039	1.404

YEAR = 84 SEASON = 1 REGION = 3

TOTAL OBSERVATIONS: 8

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	5	8	8	8	8	8
MINIMUM	18.000	19.700	22.900	0.390	7.480	3.030
MAXIMUM	29.000	47.100	25.800	7.500	8.610	9.580
MEAN	25.400	39.512	24.362	1.930	8.216	7.009
STANDARD DEV	4.336	9.210	1.049	2.497	0.394	2.346

YEAR = 84 SEASON = 2 REGION = 1

TOTAL OBSERVATIONS: 6

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	5	6	6	6	6	6
MINIMUM	30.000	40.000	30.100	1.340	8.430	2.690
MAXIMUM	40.000	59.900	32.300	9.400	8.960	9.180
MEAN	36.000	52.150	30.700	3.457	8.687	5.742
STANDARD DEV	4.062	9.451	0.817	2.985	0.237	2.828

YEAR = 84 SEASON = 2 REGION = 2

TOTAL OBSERVATIONS: 32

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	30	32	32	32	32	32
MINIMUM	34.000	53.000	24.100	0.360	8.400	5.790
MAXIMUM	42.000	61.100	30.300	1.440	8.800	8.660
MEAN	38.467	59.416	29.544	0.628	8.669	7.202
STANDARD DEV	1.306	1.493	1.045	0.231	0.082	0.721

YEAR = 84 SEASON = 2 REGION = 3

TOTAL OBSERVATIONS: 7

	SALT	COND	TEMP	TURB	PH	DO
N OF CASES	7	7	7	7	7	7
MINIMUM	36.000	54.900	29.200	0.360	8.150	3.170
MAXIMUM	40.000	60.900	31.500	2.100	9.080	8.500
MEAN	38.000	58.900	30.357	1.166	8.733	6.416
STANDARD DEV	1.291	2.039	0.772	0.688	0.328	1.855

APPENDIX 3.

COMPUTER PROGRAMS

APPENDIX 3. Computer Programs

******************** FLOW.FOR ***************************

This program combines the contents of DATE.DAT and FLOW'.DAT The output is stored in FLOW.DAT and includes the record number, the date, the Moody and the Mowry flow data for the date of water quality sampling and for four days preceeding it.

```
      dimension iflow(655,2),idate(655)
      integer moody(5),mowry(5)
      open (1,file='flow'.dat',status='old')
      open (2,file='date.dat',status='old')
      open (3,file='flow.dat',status='new')
      do 1 if=1,655
    1 read(1,4) idate(if),iflow(if,1),iflow(if,2)
      if=0
      iseq=0
      do 30 iq=1,131
      read(2,4) id,isn,ien
      do 2 i=1,5
      if=if+1
      moody(i)=iflow(if,1)
    2 mowry(i)=iflow(if,2)
    4 format(i5,1x,i4,1x,i4)
      do 12 iz=isn,ien
      iseq=iseq+1
   12 write(3,6)iseq,iz,id,(moody(i),i=1,5),(mowry(k),k=1,5)
    6 format(i4,1x,i4,1x,i5,1x,10i4)
   30 continue
      stop
      end
```

```
*********************FLOWQUAL.FOR*****************
 This program incorporates the flow data in file FLOW.DAT
 into the Bay quality data in QUAL.DAT for measurements
 from 1972 throudh 1982 inclusive. The output is stored
 in FLOWQUAL.DAT. Only Salinity, Conductivity, Temperature

 Turbidity, pH and Dissolved Oxygen are retained in addition to
 the depth of measurement.

      dimension p(12)
      integer recf,date,d(5),r(5),recq,sta,flow(5)
      open (1,file='flow.dat',status='old')
      open (2,file='qual.dat',status='old')
      open (3,file='flowqual.dat',status='new')
      do 3 i=1,3500
      read(1,6,end=7) is,recf,date,(d(k),k=1,5),(r(k),k=1,5)
      read(2,5,end=7) recq,sta,itime,(p(j),j=1,12)
      do 2 k=1,5
      flow(k)=9999
      if ( sta .eq. 2 ) flow(k)=d(k)
      if ( sta .eq. 10 .and. sta .le. 19 ) flow(k)=d(k)
      if ( sta .eq. 6 ) flow(k)=r(k)
      if ( sta .ge. 30 .and. sta .le. 39 ) flow(k)=r(k)
    2 continue
    3 write(3,8) is,date,sta,(flow(k),k=1,5),(p(j),j=1,07)
    5 format(i4,i3,i5,f5.2,3f6.2,3f5.2,f6.2,f5.2,f7.2,f5.2,f6.2)
    6 format(i4,1x,i4,1x,i5,1x,10i4)
    7 continue
    8 format(2i7,i4,2x,5i5,7f6.2)
      stop
      end
```

********************* CLUSTER.FOR ***********************

This program computes the mean, over time, for each water quality variable sampled at each location at a specific depth or averaged over a given depth. Av(l,m) is the mean value for the m th variable at the l th station. Averaging is done over the number of episodes that were sampled at this station. The output is stored in CLUSTER.DAT and is the input for the Cluster Analysis.

```
      dimension p(12),avg(66,7),iter(66)
      integer sta(66)
      data sta/ 02,04,06,07,08,11,12,13,14,15,16,18,19,21,
     1,23,24,25,26,28,29,31,32,33,34,35,36,38,39,51,52,53,
     2,54,55,58,61,62,63,64,65,68,71,72,73,74,75,78,81,82,
     3,83,84,85,88,91,92,93,94,95,96,10,20,30,50,60,70,80,
     4,90,22//
      open (1,file=qual.dat',status='old')
      open (2,file=cluster.dat,status='new')
      do 5 l=1,67
      iter(l)=0
      do 5 m=1,7
    5 avg(l,m)=0.
      do 30 n=1,4000
      read(1,80,end=40) i,ista,itime,(p(l),l=1,07)
      if(p(1) .gt. 0.20) go to 30
      do 10 l=1,7
      if(p(l) .eq. 9.99 .or. p(l) .eq. 99.99) go to 30
   10 continue
      do 20 l=1,66
      if(ista .ne. sta(l)) go to 20
      iter(l)=iter(l)+1
      do 15 m=1,7
   15 avg(l,m)=avg(l,m)+p(m)
      go to 30
   20 continue
   30 continue
   40 continue
      do 50 l=1,66
      do 60 m=1,7
      if(iter(l) .eq. 0) go to 50
   60 avg(l,m)=avg(l,m)/float(iter(l))
      write(2,70) sta(l),(avg(l,m),m=1,7)
   50 continue
   70 format(i3,7f7.2)
   80 format(i4,1x,i2,1x,i4,1x,f4.2,1x,3(f5.2,1x),
     13(f4.2,1x))
      stop
      end
```

************************ CAT.FOR **********************

This program converts the sampled values into categorical data and also obtains the frequency of each category for a given station - variable - canal combination. The output was stored in TABLE.DAT for all the variables and is given as Table 8 for the variable conductivity.

```
      dimension p(10),pcr(10),in(20),ll(20,10,5),l(5)
      integer date,sta,gg(20,10,5),gl(20,10,5),lg(20,10,5)
      open (1,file='flowqual.dat',status='old')
      open (2,file='table.dat',status='new')
      open (3,file='corre.dat',status='new')
      read(1,2) (pcr(j),j=1,10)
    2 format(5f4.0,05f5.2)
      read(1,3) (in(j),j=1,20)
    3 format(20i2)
      do 4 k=1,5
      do 4 j=1,10
      do 4 m=1,20
      gg(m,j,k)=0
      gl(m,j,k)=0
      lg(m,j,k)=0
    4 ll(m,j,k)=0
      do 16 i=1,4620
      read(1,5) iseq,date,sta,(p(j),j=1,10)
    5 format(2i7,i4,2x,5(1x,f4.0),5f6.2)
      do 15 m=1,20
      if(sta .ne. in(m)) go to 15
      do 100 j=1,10
      if(p(j) .eq. 9.99 .or. p(j) .eq. 99.99) go to 16
      if(p(j) .eq. 9999 .or. p(j) .eq. 999.99) go to 16
100   continue
      do 10 k=1,5
      do 10 j=6,10
      if(p(k).gt.pcr(j) .and. p(j).gt.pcr(j))
     1 gg(m,j,k)=gg(m,j,k)+1
      if(p(k).gt.pcr(j) .and. p(j).le.pcr(j))
     2 gl(m,j,k)=gl(m,j,k)+1
      if(p(k).le.pcr(j) .and. p(j).gt.pcr(j))
     3 lg(m,j,k)=lg(m,j,k)+1
      if(p(k).le.pcr(j) .and. p(j).le.pcr(j))
     4 ll(m,j,k)=ll(m,j,k)+1
   10 continue
      write(3,14) iseq,date,sta,(p(j),j=1,10)
   14 format(2i7,i4,2x,5f5.0,5f6.2)
   15 continue
   16 continue
      write(*,20)
   20 format(////)
      do 40 j=6,10
      i=1
      do 40 m=1,20
      if(m .gt. 10 ) i=2
      do 40 n=1,4
      do 39 k=1,5
      if(n .eq. 1) l(k)=gg(m,j,k)
```

```
   if(n .eq. 2) l(k)=gl(m,j,k)
   if(n .eq. 3) l(k)=lg(m,j,k)
   if(n .eq. 4) l(k)=ll(m,j,k)
39 continue
40 write(2,45)    n,in(m),i,j,(l(k),k=1,5)
45 format(9i4)
   stop
   end
```

**************** SEQ'.FOR ******************

This program combines the QUAL.DAT and DATE.DAT data files, and abstracts the time ordered values of a given variable sampled at a given station. The variables are identified as follows: 2=salinity, 3=conductivity, 4=temperature, 5=turbidity, 6=pH, 7=dissolved oxygen. The output is the variable value averaged over the sampled depths for the sampling date. It was stored in DATA11.DAT for station 11 and so on. To run the program enter the station number and the variable number on the same line.

```
      dimension p(4)
      integer sta
      open (1,file='qual.dat',status='old')
      open (2,file='date.dat',status='old')
      open (3,file='        ',status='new')
      read(*,*) sta,ivar
      do 30 j=1,131
      n=0
      sum=0.
      read(2,50) idate,isn,ien
      do 20 l=isn,ien
      read(1,80) i,ista,itime,(p(k),k=1,4)
      if(ista .ne. sta) go to 20
      if(p(ivar) .eq. 99.99) go to 20
      n=n+1
      sum=sum + p(ivar)
   20 continue
      if(n .eq. 0) go to 30
      avg= sum/float(n)
      write(3,90) j,idate,n,sum,avg
   30 continue
   50 format(i5,1x,i4,1x,i4)
   80 format(i4,1x,i2,1x,i4,1x,f4.2,1x,3(f5.2,1x))
   90 format(3i7,2x,2f7.2)
      stop
      end
```

********************** SE.FOR ***********************

This program assigns the sampled dates in DATA11.DAT, for example, to the month within which it falls. The output is the depth-averaged variable value now averaged over the number of sampling days within the month and was stored in S11.DAT for station 11.

```
      dimension  ndate(150),idate(131),a(131),avg(145)
      open (1,file='ndate.dat',status='old')
      open (2,file='           ',status='old')
      open (3,file='           ',status='new')
      ndate(1)=72000
      read(1,45) (ndate(k),k=2,145)
      do 05 j=1,131
      read(2,50,end=06) ij,idate(j),no,s,a(j)
   05 jmax=j
   06 continue
      do 30 i=2,145
      sum=0.
      n=0
      do 10 j=1,jmax
      if(idate(j) .ge. ndate(i) .or. idate(j) .lt. ndate(i-1)) go
     1 to 10
      n=n+1
      sum=sum+a(j)
   10 continue
      if(n .gt. 0) then
      avg(i-1)=sum/float(n)
      i1=i-1
      write(3,55)  i1,ndate(i-1),ndate(i),n,avg(i-1)
      else
      avg(i-1)=99.99
      i1=i-1
      write(3,55)  i1,ndate(i-1),ndate(i),n,avg(i-1)
      endif
   30 continue
   40 continue
   45 format(15(10i7/))
   50 format(3i7,2f9.2)
   55 format(4i7,f7.2)
      stop
      end
```

******************** SS.FOR **********************

This program partitions the data file, S11.DAT for station 11, into time segments of uninterupted monthly data. It then computes, for each segment, the total score (S), Kendall rank correlation coefficient (tau), standard deviation of the score (std), and the reduced variate (u).

```
      dimension id(200,4),c(200),ns(20)
      integer sta
      open(1,file='         ',status='old')
      open(2,file='         ',status='new')
      read(*,*) sta,nseg,(ns(mm),mm=1,nseg)
      do 1 i=1,200
      read(1,3,end=2) (id(i,j),j=1,4),c(i)
    1 nobs=i
    2 continue
    3 format(4i7,f7.2) c
      nstart=1
      nend=ns(1)
      do 1000 mm=1,nseg
      n=ns(mm)
      s=0
      nend1=nend-1
      do 65 i=nstart,nend1
      m=i+1
      do 63 l=m,nend
      diff=c(i)-c(l)
      if(diff .gt. 0.) d=1
      if(diff .eq. 0.) d=0
      if(diff .lt. 0.) d=-1
   63 s=s+d
   65 continue
      tau=s/(0.5 * float(n*n-n))
      var=0.0555555*n*(n-1)*(2*n+5)
      std=sqrt(var)
      u=(s-1.)/std
      write(2,80) sta,id(nstart,2),id(nend,3),n,s,tau,std,u
      nstart=nend + 1
      nend=nend+ns(mm+1)
 1000 continue
   80 format(4i7,4f10.2)
      STOP
```

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